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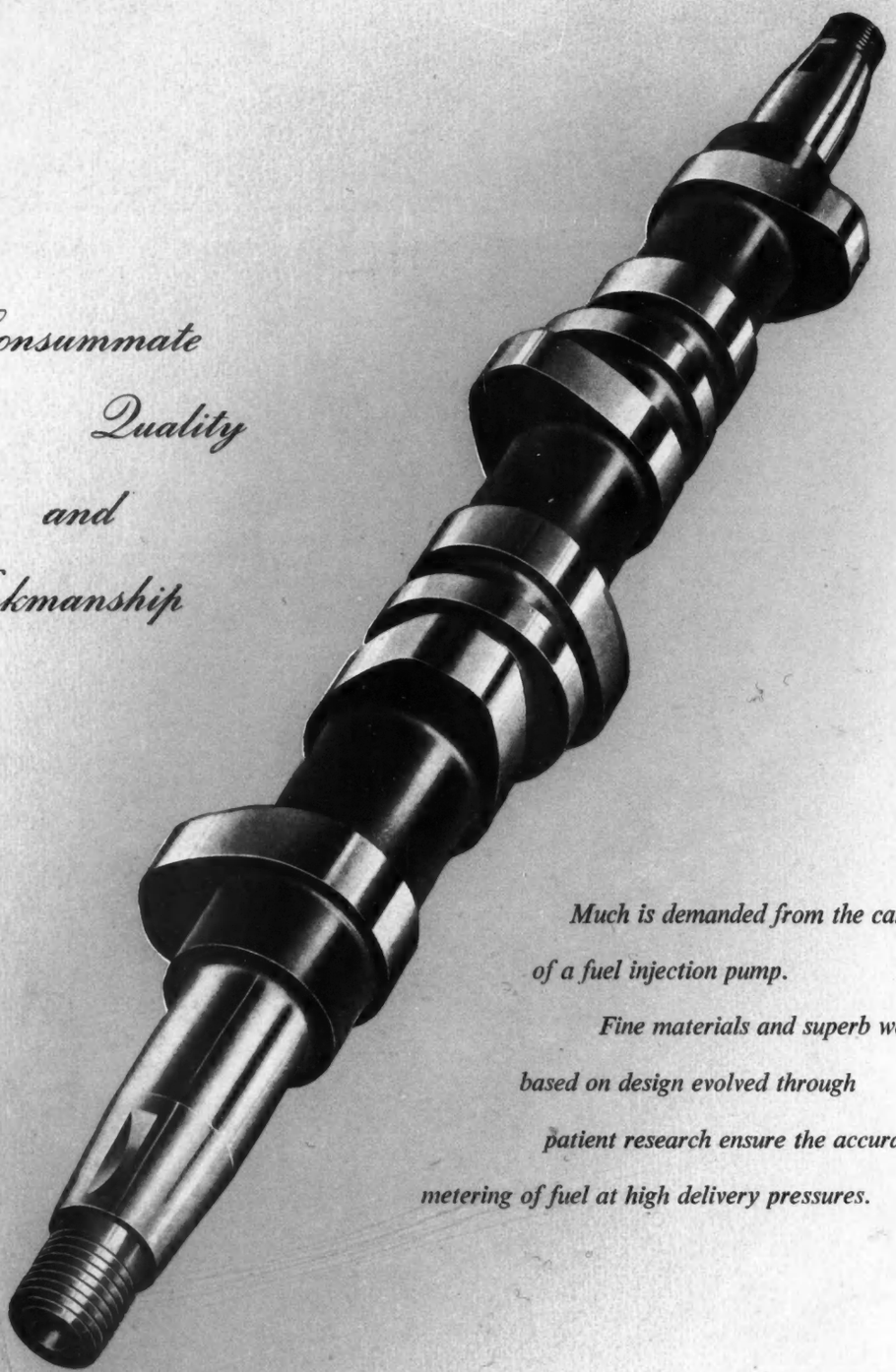

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INTELLIGENCE

WHEN Sir Anthony Eden was answering the questions of newspaper correspondents in a television programme last week, he said that so many telegrams were received at the Foreign Office that if he were to do nothing but read them continuously every day he would hardly keep pace with them. He was answering a question about the change in Foreign Office work since he went there 28 years ago. Before he turned to a further question he just had time to indicate the complexity of the organisation needed to handle the present volume of diplomatic material, and to ensure that each item is dealt with at the appropriate level. It would have been interesting to hear him explain the principles on which the system is based. Clearly, it must be able to measure the relative significance of everything received, and to measure it with great sensitivity, otherwise a subject that is potentially of fundamental importance might be dismissed rather summarily at a low level.

An engineer with any degree of executive responsibility works in similar circumstances, though on an altogether different plane. Soldiers have a useful word—" intelligence " —which can be used in this context to denote every kind of information which an engineer receives. Apart from the obvious sources such as correspondence, internal reports and external publications, his mind is bombarded with messages in many other ways. By walking round the shops, or visiting a site, visual observation conveys a host of impressions which the mind sieves almost automatically. Some engineers are better at this than others. One whom we recall had a most receptive mind although he was near retiring age. He would sometimes stop to examine a prosaic-looking part or assembly because he wanted to know how it was designed and produced. As a result he had such a fund of knowledge and experience that he would confidently tackle any job he was given.

Another engineer was remarkably proficient in acquiring information by listening to his staff—and others—talking. He would interrupt occasionally with a query or comment, which he worded carefully so as to elicit the information he required. Some of his colleagues remarked, rather unkindly, that he lived by picking other folk's brains, but the truth was that, like a professional soldier, he knew that effective orders can only be based on adequate intelligence.

For many engineers the most fruitful intelligence comes from those whom they serve—the customers. It is easy to produce a design that is based on the minimum of information relating to the users' requirements, but such a design is likely to prove a failure in service. It is hard, but rewarding, to study the users' requirements—to study them in the broadest sense by, for example, perceiving factors of which the user himself is unaware. It is not a task to be done once and then forgotten; it must always be in mind, so that the vaguest sign of a new factor is recognised immediately.

Written, visual and aural intelligence—it is an ever-flowing tide. As engineers, are we trained to sift it? An engineering education encourages the habit of giving undivided attention to each problem, working on it until a final solution is reached. But there is a danger associated with this habit of mind. The danger is that, ultimately, we give too much attention to a few things—usually those which for various reasons cannot be ignored. But things which cannot be ignored are not always those which are potentially of the greatest value. The most-advertised washing powder is not necessarily the best; similarly, the most pressing and obvious problems are not necessarily those to which an executive should give most of his attention. Some useful research could be done by attempting to measure the impact, on the mind, of intelligence coming from various sources and presented in various ways, because it is the source and manner of presentation which largely condition and determine the pattern of a man's work; not—as many would like to believe—his ability to impose a plan on his work.

Even with the present volume of social-science research it is not likely that anyone will attempt such an inquiry on a broad scale, but it can be done individually. One can list all the sources of intelligence and analyse each in respect of its force of impact, its importance, the time it takes up, etc. Eventually, a more effective pattern of work should emerge: some matters which regularly shout loudly to attract attention are found to be of minor significance, whereas others which have no inherent publicity-force, and therefore tend to be neglected, are revealed as subjects of vital importance. It is then possible to impose a new pattern: to reject or delegate the trivial, however insistent it may be; to elevate other factors to their proper position; and even to bring in factors which were previously ignored. Such a re-assessment can be carried out periodically, and the pattern of work kept under review more or less continually. The advantages to a senior executive are obvious, but they are important to any engineer, because engineering is creative work. Routine and habit are powerful allies in production, but they become the enemies of the individual engineer if they are allowed to regulate his perceptiveness and thinking.

Weekly Survey

CIVIL AND CONSULTING ENGINEERS ABROAD

The remarks of the chairman of Sir Lindsay Parkinson and Company, Limited, that accompanied the accounts for the year 1953 have once more drawn attention to the unremitting and, on the whole, successful struggle of British contractors and consulting engineers to win business against keen competition. Sir Lindsay Parkinson and Company are able to report increasing turnover for the Canadian subsidiary at Toronto, joint participation in an £8 million contract for the new harbour in the Gold Coast, but they also comment on the keen competition in Australia. These specific points in the case of one company hint at the general experience of British contracting firms abroad.

Civil engineering work overseas has always tended to attract a certain type of engineering mentality, for the rewards of success have been high although the risk of failure has been correspondingly great. The fortunes of individual companies have varied from one generation to another but, overall, British consulting engineers and civil engineering concerns specialising in overseas work have thrived on competition and risk-taking both inside and outside the Commonwealth.

To-day the challenge is particularly complex. Severe competition continues to be felt from the United States where the large consultant contractor can make a special appeal, very often by offering finance as well as making an orthodox bid for a contract. Again, the sheer size of contracts is making it necessary for firms to join forces and in some cases where nationalism is rampant a local company may have to be taken on as a partner in a particular contract. Temporary combinations of companies have become a feature in this field. As long ago as 1940 British contractors formed the Export Group for Constructional Industries and this was more recently used as an intelligence service in dealing with the St. Lawrence Seaway developments. The Owen Falls hydro-electric development project was handled by eight companies of British, Danish and Dutch origin.

Complexity has therefore had to engender flexibility. Concerns have had to adapt their techniques of tendering and executing contracts to a changing world. The need for these kind of developments in consultancy practice may be deplored, but the energetic steps which have been made to improvise in order to meet them is a sign of a healthy resistance and adaptability which aug urs well for British engineering abroad.

* * *

CAPITAL FOR SMALL COMPANIES

There is still a shortage of risk capital for the small concern, according to the inaugural address which Lord Piercy, chairman of the Industrial and Commercial Finance Corporation, delivered recently as President of the Royal Statistical Society. His views on this subject are all the more significant since he has been head for a number of years of an organisation which specialises in the provision of finance to medium-sized businesses. This lack of finance for enterprises which are too small to attract the services of the London and Provincial capital markets was known in the 1930's as the " Macmillan gap" and Lord Piercy is of the opinion that this gap is still with us.

On balance it is probably somewhat easier for the small business, say, the small engineering concern in Birmingham or Glasgow, to raise new capital than it was 25 years ago, but the shift in the balance has been small. In addition to the facilities of organisations like Lord Piercy's, there are a number of other institutions which are prepared to groom small businesses for ultimate offer to the investing public. The number of concerns coming forward for such treatment is increasing, but not always for new capital. The pressure of death duties is enhancing the attractions for directors and senior partners of taking capital gains while they can, to put their assets in a more liquid form against the ultimate requirements of the Inland Revenue. On the other hand the private investor with liquid resources available for investment in small ventures is becoming a rarity, and in a period of prolonged inflation small concerns have been able to accumulate sufficient profits in many cases to provide their own finance, provided that expansion can be undertaken at a moderate pace. Lord Piercy is of the view that the present tax system is hard on new enterprises and that they should be allowed to write off their fixed assets much more quickly than at present.

It should not be thought that because the balance has shifted slightly more favourably for the small concern that a complacent attitude can be adopted. This country remains primarily an economy of small companies and much of its dynamism must come from small businesses which are run by one man or a small group of men with direct oversight of all the concern's activities. There can never be an adequate supply of medium and large-sized efficient companies if small efficient concerns are hampered in their growth by lack of capital. It will be interesting to see if the welcome increase in savings by the general public which has been apparent since 1952 can percolate in the next few years through the highly-organised capital markets in the large towns to the smaller businesses everywhere.

* * *

SCOTTISH ROADS

It was announced in the House of Commons last week that the policy decisions and the administration of the Scottish road system is to be transferred from the Minister of Transport to the Secretary of State for Scotland. Thus a further and possible very significant step has been taken in the decentralisation of Scottish affairs from London to Edinburgh. Such a development is in line with the recommendations made recently by the Royal Commission on Scottish Affairs which advocated a broad policy of decentralisation of Government activities from Whitehall to the Scottish capital.

The effect of the change should be to bring the improvement of Scotland's road system to a higher level of the Government for consideration. Such perennial problems as the road systems in the Highlands and the road bridge over the Forth will now become issues for the Secretary of State for Scotland to handle at cabinet level instead of the Minister of Transport. It should be possible for the Scottish case to be made with great insistence by the former, for he is less likely to be subject to pressure from officials in London to keep Scotland's financial requirements (so far as road development is concerned) within some preconceived limits which fit the nation's road programme as a whole.

There are, however, indications, which are referred to in another note in this issue, that the roads are going to receive a higher priority for capital investment in the next few years than they have had to endure in the past. It may, therefore, be, in the event, that the Scottish road system will benefit more from this general improved priority for the road system than from the devolution of control of Scottish roads to Edinburgh. If this should be so, an improved road system in Scotland would have less to do with decentralisation from Whitehall than some of the more ardent spirits over the border will be prepared to admit.

* * *

FORD AND RANSOMES

Nine years ago, in October, 1945, Ransomes Sims and Jefferies Limited, and the Ford Motor Company, Limited, concluded a working arrangement whereby agricultural tools could be matched to a tractor. It was agreed to develop and produce jointly a basic range of implements of the mounted type which would fit Ford's three-point linkage system, and that these implements should be marketed under the trade mark F-R. During the first stage of the arrangement, the implements were made at the Ford factory at Leamington; in the second, they have been made both at Leamington and at Ipswich; and the New Year will see the beginning of the third stage when all will be made at Ipswich and the Leamington factory will be converted for other purposes.

From January, therefore, all implements in the F-R range will be made by Ransomes and will be available to both Ford and Ransomes dealers in this country. Abroad, they will be handled by Ford's as at present. In order to give a full range of farm machinery, many other implements will be available to supplement the F-R range and will be sold under the new trade mark of F-R Nacton. To manufacture these a new factory at Nacton, near Ipswich, has been built and will be in full production next year. This factory will double the floor area at present available. Several new implements are being introduced, including a tractor-drawn combine harvester with a cut of four feet.

The Fordson Major Diesel tractor, introduced three years ago, has proved very popular. Over 100,000 have been sold in the three years and during this year they have been exported to dollar-account countries to the value of over 10 million dols. in seven months—the United States being the largest single overseas market. The latest list of mounted implements in the F-R range names over 40 items including ploughs, cultivators, crop lifters and harrows. Five types (with eleven variants) are new to the range. To complete the list of equipment which can be used with this tractor there must be added implements of the F-R Nacton range, and such machines as the combine harvester mentioned above, a pick-up baler, thrashers and shellers covering almost all aspects of farm work.

* * *

HIRE PURCHASE AND APPLIANCE SALES

Weekly Survey for July 23 drew attention to the probable effect of the relaxation of hire-purchase controls on the sale of electrical consumer goods such as radio and television sets, refrigeration and washing machines. Figures recently issued show that home sales of both radio and television sets rose substantially in August, a month when there is usually a sharp decline due to expenditure on holidays. Sales of radio sets in August were 4 per cent. above those for July and nearly 60 per cent. above those for August, 1953. Radiograms were up by 25 per cent. compared with July and over 160 per cent. compared with August, 1953, while the corresponding figures for television sets were 7½ per cent. and 67 per cent., respectively. Exports have been well

maintained and in the case of television sets have risen appreciably, with the result that production for the remaining months of the year looks like being well above the corresponding figures for 1953. In the case of refrigerators, production in the first nine months of 1954 was 34 per cent. higher than in the corresponding period of 1953 in spite of the very bad turnover which might have been expected to have caused a fall in home sales.

This experience is paralleled in other fields of hire-purchase business, particularly in motor vehicles and in industrial and agricultural machinery. Hire Purchase Information, the largest organisation to record transactions in the field of motor vehicles, cycles, industrial and agricultural machinery, aircraft and caravans, show that 49,612 contracts were registered during October. This compares with an average of 45,000 in the first six months of the year but is 37 per cent. higher than in October, 1953.

Since the war the use of hire purchase has spread to a much wider section of the population than was formerly the case. It has been estimated that three-quarters of the retail trade in furniture is now on hire purchase; 10 per cent. in the case of new private cars; 25 per cent. for motor cycles; 30 per cent. for second-hand cars. This raises the question whether it will be possible to find the finance necessary to meet the full demand. It is generally considered that if the ruling Treasury controls were removed there would be no difficulty since the profit margin is fairly high (though not, in the case of fairly high-priced articles, as high as is commonly believed) and the risk of bad debts relatively small. Although special restrictions on Bank finance for hire purchase have been eased, new capital for high-purchase finance firms is still controlled beyond £50,000 in any one year, and in general new capital in excess of £50,000 is not sanctioned where the hire-purchase finance is for consumer goods. The effect has been the creation of a very large number of new companies with capital in the region of £50,000. If restrictions are eventually removed intense competition may well develop in this field. For the present, however, there appears to be no immediate threat of serious restriction of hire-purchase sales due to lack of finance.

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ROAD EXPENDITURE

The measures announced last week by the Ministry of Transport and Civil Aviation to mitigate the London traffic problem do not perhaps seem very important in relation to the magnitude of the road-improvement programme which it is generally admitted will have to be undertaken in the near future. However, the Minister himself described them as "interim measures . . . practicable within the existing financial and legislative framework," and it is generally expected that more far-reaching proposals will be announced before the end of the year.

The schemes announced by the Minister involve a total cost to the Treasury of £20 million. They provide for the Cromwell-road extension scheme at a cost of £3 million from the Exchequer, and the recommencement of work on the Dartford/Purfleet tunnel which will require £9 million from the Exchequer. In addition the Minister said he expected soon to be able to give approval to the first instalment of the New Route 11, planned by the City Corporation between Aldersgate-street and Moorgate, which is to incorporate an underground car park beneath the road. Smaller schemes include the widening of Piccadilly near Swallow-street and the widening of 1½ miles of the Great Cambridge-road from the North Circular-road to Bury-street, Edmonton.

Last April the British Road Federation suggested that £50 million a year for ten years must be spent on new road construction and called for the setting up of a National Highway Authority to borrow the necessary money, the loans being serviced by the Treasury out of taxation. Under present conditions of full employment, however, the problem is less one of finance than of the diversion of investment resources from other fields. That there is great scope for such diversion is shown by the figures for relative expenditure: new road construction has cost about £8½ million a year over the last six years while the total output of building and civil-engineering firms on new work in the first six months of 1954 was running at the rate of £1,082 million a year.

The Parliamentary Secretary, Ministry of Transport, recently stressed the length of time required before actual work on new road construction could begin. The survey alone, including consultations with the local interests involved, might take several years; the making of the statutory order, including the allowance of time for objections and, if necessary, for a public inquiry, seldom took less than a year; and finally came the preparation of detailed engineering plans and the acquisition of the land, though these could often be put in hand simultaneously. It is not therefore feasible to expect any very rapid increase in the volume of new road construction but it may be hoped that new schemes will be undertaken in sufficient number to ensure a steady increase in the work in progress.

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MACHINES AT SITE

For a week up to last Saturday, November 20, the exhibition halls at Olympia were the scene of a vast display of machinery and equipment and of demonstrations of processes concerned with public works and civil engineering generally. Attendances were reported to be high, particularly from overseas, and many firms completed long order lists specially for Africa, the Middle East and the Indian sub-continent. The interest of many visitors from both home and overseas was concentrated on road-making machinery, particularly the plant and the processes associated with soil stabilisation.

A number of trends in design and availability of machine types were to be observed. Almost without exception there has been a heavy shift towards the use of the hydraulic transmission of power and control for tractor-mounted equipment and to pneumatic power for hand tools. Matched equipment—'dozer blades, shovel-loaders, scrapers, rippers, etc.—built for successful crawler tractors were a feature of the exhibition, though a re-introduction of wheeled tractors was to be noted on some stands. The capacity range of equipment has been extended in both directions: to larger and larger machines for use on the most extensive civil-engineering contracts and to smaller versions of bull-dozers, scrapers, and trenchers for economical use on small building sites. Although the basis of nearly all these machines was a Diesel engine—and at least one maker used the exhibition to introduce a new range of engines—a small gas turbine was displayed as the prime-mover in a portable generator set.

The displays were not limited to site machinery, however; at least one stand had a splendid display of shovels, picks and forks—still indispensable implements, even though they may not be required in such numbers as hitherto. The advent of more testing and closer inspection of materials was marked by the presence of several firms, some of whom have a long record as makers of laboratory instruments and who are now also making the new apparatus, as well as others who have been formed to devote their activities to the production of soil and cement-testing equipment. Neither were the offices and design offices neglected, for several stands displayed the means of reducing and quickening routine clerical work. Clearly, the building and civil-engineering industries are taking full advantage of developments in many fields.

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DOCKS FOR OIL TANKERS

The increased sea traffic in crude oil and refined petroleum products since the war has placed heavy demands on tanker fleets. Consequently, there is at present a special need for docks capable of providing large tankers with facilities for servicing and maintenance. It is with this in mind that the Milford Docks Company have undertaken an extensive development programme for the docks at Milford Haven, where there is one of the finest natural harbours in Great Britain. The first part of the scheme, which is to be accomplished in two phases, is now almost complete.

The first phase has involved the modernisation of the existing dry dock and the installation of machine shops and dockside services, including an oily-water separator plant. The 600-ft. dock will, it is hoped, be ready early in the new year to accommodate shipping, and, in particular, tankers up to 12,500-tons displacement and 64-ft. beam.

The second phase of the project is to include the building of a new dry dock, 800 ft. long by 110 ft. wide. The war-time Mulberry harbour principle is to be used in its construction and it will be capable of accommodating tankers up to the 45,000-ton class. In addition to wet basins, with space for two ships of this size, it will have a lay-by berth, and it is expected that the work, which is to commence about the end of May, 1955, will be completed in two years. The consulting engineers for this scheme are Maunsell, Posford and Pavry.

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THE BILLIARD CUE

Accles and Pollock, Limited, have announced, with justifiable pride, that they have succeeded in producing a billiard cue of tubular metal. The best measure of their success is that Mr. Joe Davis, world snooker champion for 20 years, has said he will play with the new Apollo cue, as it has been named. Compared with the traditional wooden cue it has the advantage that it will not warp, bend, twist or split. It is being made in three weights—16, 16½ and 17 oz.—and any cue will match exactly with any other of the same weight. An aluminium alloy, T.I.223, is employed.

The mechanics of billiard cues were studied. When a ball is hit the cue is momentarily compressed longitudinally. If a shot is played with "side" the tip of the cue is deflected. Other factors include vibration, balance, noise, and "power," i.e., the efficiency of the cue in converting the energy exerted by the player into the forward movement of the ball. It was found that a balance weight at the butt end of the cue caused excessive vibration, the cue bouncing back from the ball after striking. A solution was found by inserting a tubular steel liner in the cue at the vibration antinode. This, coupled with the damping action of two rubber inserts, gives a playing response identical with that of the best type of wooden cue.

TECHNICAL EVIDENCE AT THE COMET INQUIRY

Continued from page 651

When the Inquiry resumed at the Institution of Civil Engineers on Wednesday, November 17, Mr. Harry Povey, a director of the de Havilland Aircraft Company, Limited, continued his evidence dealing with manufacturing cracks in aircraft. He said that manufacturing cracks were usually covered by concession notes which the operators of the aircraft would know about.

Replying to Mr. R. A. McCrindle, representing the British Airline Pilots' Association, Mr. Povey said the inspection department was adequate to deal with the job it was performing and was constantly under review.

Mr. McCrindle: That is subject to any human errors that might creep in ?—Yes.

Special magnetic and fluorescent equipment was used in the detection of cracks. They made a great attempt to eliminate the possibility of incipient cracks.

Mr. John Wilkins, assistant chief designer of the de Havilland Aircraft Company, agreed that there was a remote chance of damage to the wing through pressure refuelling, but such damage was not likely to endanger the aircraft.

He was examined by Mr. H. A. P. Fisher, one of de Havillands' counsel, who asked " Is it correct that, although you knew the chance of damage was very remote, de Havillands are in fact considering ways and means of preventing even this remote damage ? "

Mr. Wilkins : Yes.

Mr. Fisher: You have a number of solutions under consideration but would not be anxious at this stage to particularise any of them ?—They are still under development and we would not like to mention them at present.

FUEL VENTING

Mr. Fisher: Coming on to the question of fuel venting, I think it is true to say, is it not, that since the Comet first flew you have been aware that fuel might vent from the pipes and reach the area of jet pipes ?—Yes. In common with other aircraft a certain amount of vapour can escape to other parts of the aircraft. Kerosine does not evaporate so readily as petrol and would have more chance of reaching other parts.

Mr. Fisher: What are your views as to the extent of danger to the aircraft in the event of fuel reaching the area of the jet pipes ? Have you formed an opinion as to the amount of kerosine in the Comet as originally designed, which can vent from the pipe during take-off and early stages of flight ?—Yes. We have done tests and calculations to show that after 1½ minutes of the unstick point no fuel can run freely out of the vent; 6½ Imperial gallons could escape. The vast majority would be blown straight backwards and only that cut out by turbulent airflow in the constrictor would find its way, with some difficulty, into the jet pipes.

Mr. Fisher: Have you formed a view by means of tests as to the amount of fuel which could possibly reach the jet-pipe area on any one occasion ?—We have done a test which showed that the fuel did not in fact get any further inboard than the rib outboard of the inboard jet pipe. A sprinkling did get in the area forward of the flap.

Mr. Fisher: In the area in which you found fuel would get, what was the amount ?—All one can say is that it was a very small amount. There are five drains in that area capable of dealing with ten pints of fuel a minute. That would be enough to prevent any accumulation of fuel in the area.

Mr. Fisher then asked about tests which had been carried out to find out whether there was any chance of fuel becoming ignited by reaching that area and Mr. Wilkins said that although their tests had not shown the temperature on the jet-pipe shroud as more than 300 deg. C. he would accept Sir Arnold Hall's figure of 350 deg.

Referring to Sir Arnold's quotation of the ignition point of kerosine as 250 deg. C., Mr. Wilkins said that would be in warm conditions and in the closed container. In open flat conditions the temperature for ignition would be 650 deg. C.

He added that the area near the jet-pipe shroud was more open than the test area from which the figures were derived and the Esso Petroleum Company had agreed with the de Havilland view. The area was extremely well ventilated, which again reduced the chance of ignition.

During tests they sprayed kerosine directly on to the shroud and no ignition occurred.

In 1954 they carried out a number of other tests. They discovered that Lockheed fuel, which they used for tests, behaved very similarly to kerosine. They sprayed Lockheed fuel on to the shroud where the temperature was 300 deg. C. and obtained no ignition. They sprayed it between the jet pipe and shroud where the temperature was 400 deg. C. and again obtained no ignition.

Mr. Wilkins went on: I should say the risk of fire is negligible although de Havillands have constantly been seeking a way of preventing the fuel reaching this area. In April, 1953, we introduced modification number 755 which was intended to stop fuel venting from the tank. It raised the highest point of the vent pipe above the highest point of the fuel. After the Elba accident we made modification 755 mandatory and it was introduced on all aircraft before resumption of service. All our tests showed that that modification was successful in preventing fuel venting from the tank. Later, we received information from South African Airways that they still had venting despite the modification and we concluded that although the level of the highest point of the pipe was above the level of the fuel it could syphon if the pipe and auxiliary vent pipe were full of fuel. We introduced another modification in the form of a syphon brake to prevent that. That was tested at Farnborough and proved satisfactory. We also introduced a number of other modifications to prevent any fuel, which escaped despite this modification, from reaching the danger area.

Mr. Wilkins was asked by the chairman about the risk of damage to the aircraft either from the passengers' ladder or from knocking by heavy baggage at the point of entry of passengers, crew and baggage.

Mr. Wilkins said a reinforcing plate had been put on the passengers' door to protect it against damage from the steps and such things.

The Chairman: Is not the risk as great or greater on the luggage door ? Surely it would take a great many humans to do damage to the frame ?

Mr. Wilkins said it was not so great as the luggage door was underneath. Reinforcing plates had been put where practice had shown they were necessary.

He added: " I would say that if damage were to occur it would be readily seen because these plates are constantly under observation."

One of the assessors, Sir William Scott Farren, raised the question of the cracks and said " We have heard such a lot in this Inquiry about the consequence of cracks and the queer way in which these cracks can spread with this high pressure inside."

Sir William: I was wondering if you are quite satisfied about the ability to detect a crack in time to make quite sure you repaired it. Whether in fact the skin round the entrances are robust enough or whether people are treating it without recognition of the need for special care?—I do not think in the first place you would get a crack. You would get a dent which is not the same thing and it would depend whether it was in a highly stressed portion of the shell or not. It would depend entirely where the dent appeared, and, if it had nothing whatever to do with the pressurisation itself, my opinion is that it would not be dangerous.

Sir William: I believe some of the cabin structure round the bottom of the belly is inside the pressurised area and some outside?—Yes.

Sir William: Are you satisfied that the repair policy, if I may call it that, is entirely satisfactory? You have to discover the thing and correct it before it is too late.

Mr. Wilkins asked: " Are you thinking of pressure-cabin failure," to which Sir William replied " Yes."

Mr. Wilkins: That is rather a difficult one to answer but I think so far the operators have dealt with that situation quite satisfactorily.

CABIN-PRESSURE SAFETY VALVE

Sir William asked about the pressurised system after Mr. Wilkins had agreed that Yoke Peter's accident was due to the pressurised cabin failure.

The failure, said Sir William, would be either because the structure was too weak or because the pressure went up. One way was by some failure of the system equivalent to sitting on the safety valve, and he asked Mr. Wilkins for his views.

Mr. Wilkins said there were three valves, two discharge valves and a safety valve. The safety valve operated if the pressure increased to more than 8½ lb. per square inch and would blow off to relieve the pressure.

Sir William asked if Mr. Wilkins was satisfied that the probability of the safety valve becoming blocked at any time was so remote that it would be a safe expedient, and Mr. Wilkins replied that the safety valve itself had a manual over-ride, a mechanical one not relying on any tricks of pressure or anything else. If the pressure in the cabin were rising at a high rate the engineer could open the valve. At 35,000 feet there was not enough air delivered from the engines to build up the pressure very rapidly and there would have been ample time for the engineer to find something wrong. At high altitude it took a long time to make itself known, and he had no doubt it would have become apparent. A very high pressure indeed would be needed to burst the cabin.

In reply to another question Mr. Wilkins said they were considering a re-design of the blow-off valve in a manner which would make it much less likely to ice up.

At this point Sir Hartley Shawcross intimated that he had concluded the evidence on behalf of the de Havilland company.

STRESS CALCULATION

Sir Lionel Heald then handed in as an exhibit an agreed statement concerning stress calculations made by the de Havilland Company in 1947, and by Sir Arnold Hall in November, 1954.

The statement said:—

(1) It is common ground between Sir Arnold Hall and Messrs. de Havillands that in ordinary and proper design practice reliance would not be placed upon calculations except as a preliminary approach before testing.

(2) Both sets of calculations have been examined and it is accepted that no mathematical error or misapplication of principles exists.

(3) Messrs de Havillands' calculations were made merely in order to forecast the ultimate static stress at which failure would occur on test in the area surrounding a typical cut out where the window frame is riveted to the skin; for this purpose of preparing for a test in 1947, the calculations were soundly formulated.

(4) Messrs. de Havillands' have found Sir Arnold Hall's note on this problem of calculation of very great interest and regard it as a most valuable as well as novel contribution to the philosophy on this topic of which important use will be made in the future.

(5) It is agreed that there must be present, in the region adjoining the cut-out, stresses sufficient in conjunction with local stress raisers to cause the fatigue which is believed to have been the cause of the accident, but the pursuit of any question as to the precise value and location of such stresses is considered to be irrelevant for the purposes of this inquiry.

The court then recalled Sir Arnold Hall for further questioning on some of the points which had arisen from his evidence and from the agreed statement on calculations.

Sir Arnold said that the calculations he made could have been worked out by the de Havilland company in 1946, had they wanted to do so because the fundamental mathematics had been published in 1945.

At this point Sir Hartley Shawcross asked: " Is it a fact that in the calculations which you were good enough to do, you adapted something published in a Royal Society paper in 1945? "

Sir Arnold replied that that was so. He had not seen it done before but he did not think it was very difficult.

After discussing with Sir Arnold the method used in estimating theoretical higher stresses Sir William Scott Farren asked: Do these calculations apply only when the material in question is completely within the elastic range of every point in it?

Sir Arnold agreed. It was fair because they were calculating a stress below the proof stress. The aeroplane should be operating in flight below proof.

Sir William: If we come to smaller cut-outs the same principle of calculation would apply, but might you find more difficulty in making experimental tests?—It depends on the specific geometry. If you had in mind a large cut-out with a small rivet hole near it, it would be difficult. I think you could make a good shot at a large concentration with a large cut-out and riveting which would give useful guidance.

Sir William: Suppose you put a load up so that the stresses now in certain places are obviously above that at which the material begins to yield as a ductile material, what then is likely to be the influence of that?

Sir Arnold: I think the material readjusts itself. Once you have got to the plastic range the material will flow or move without any addition of stress to, in fact, keep the stress at the elastic limit providing you are not calling on the material to do more than it can do.

Sir William: Does it follow that the material is quite able to distort plastically to such an extent as to bring, over quite considerable areas of material in a large cut-out, a considerable reduction of stress?—No, I think what it does is to limit the stress to something like the proof stress. It is more an ending of the increase.

RAPID CRACK SPREAD

Sir William then questioned the witness on cracks in structures such as pressure cabins and pointed out that one of the methods which had been under discussion and caused a certain amount of puzzlement in some peoples' minds was the very rapid spread of some sorts of cracks compared with the comparatively slow spread of cracks which in their early stages seemed to be almost indistinguishable.

He commented that a crack photographed on Yoke Uncle was regarded by Sir Arnold and by the de Havilland Company as an imminent failure and therefore they did not go on with the tests. They found, he pointed out, that after the first failure another crack had spread. That had happened not at a high internal pressure relative to the ultimate strength of the cabin but at roughly the working load.

Could Sir Arnold suggest, he asked, any simple physical explanation of that? How would he explain the different behaviour of those two cracks, one of which did spread and one of which did not?

Sir Arnold replied "There is quite a lot to learn about this matter. I cannot give you a comprehensive answer because it is not fully understood. I must first draw the distinction between the kind of crack on the wing of Yoke Uncle which was a slow crack and a crack in a pressure cabin. If you take a position like the wheel-well on the Comet, once the crack has formed you have redistributed the local load. It is like taking a piece of paper you are pulling tight and a snip relieves the load. The general load in that area is quite low. If I were pulling it tight over the whole thing, once I put a nick there it would tear right through.

"When the crack forms in an area of high stress the crack is encouraged to run forward, having behind it a considerable stress, and it will run rapidly across.

"There is one other consideration to bear in mind and that is that some of these cracks run into rivet holes and are located. Others run between rivet holes and it is a random matter. If they run into a rivet hole they may stay there, but if they go in between they may catch a hole at the next line of rivets or go through again, and if they do the result is quite catastrophic."

Sir Arnold said the general stress was high. If they compared the stress in the skin of the cabin with the stress in the skin under the wing near the wheel-well they would probably find the cabin stress much higher. The whole answer depended very largely he said on what was the stress field.

Referring again to the Comet Yoke Uncle, Sir William asked whether the crack involved in the collapse of Yoke Uncle, where it had spread across one cabin window, had stretched some quite appreciable distance, say an inch or two, on an earlier pressurisation.

Sir Arnold replied: "I think a crack, at any rate ¼-in. to ½-in. in length had existed for some time. The reason we know that is that our tank water grew algae, and we found some traces of it in the crack. I cannot make any estimate of how long, but it had apparently existed for long enough to get a green stain on it before it finally shattered."

LIFE SCATTER

Sir William then turned to the question of "scatter" in structures under repeated loads.

He said: "We have heard a great deal of the large variation in the number of applications of load to be made to produce a failure according to the level of stress of these loads, which is called, I believe, "scatter," and the figures given are stated quite arbitrarily and with a suspicious roundness of one third in one direction and three times in another. In other words there is an uncertainty of 10 to 1 or thereabouts in the probable life of anything you design when it is subjected to alternating loads. What is the evidence for that in this kind of structure?"

Sir Arnold: Clearly we have not a large number of pressure-cabin tests on which we can draw. The best we can do is to draw on our general experience. We have experience of a variety of types of structure but it is true there is no evidence of any other experiment showing this range but I could put in a set of test results which will show the kind of thing that happens. It has been suggested the 9-to-1 spread would not apply in this case on the grounds that you had 18 specimens in the 18 windows. This is not correct. It is our experience that when you have things of that kind you get about 9 to 1. I have got an experiemental test result on 24 specimens with nine points of potential failure; each point did fail on one or other of the specimens, and the total spread is 10-to-1.

Sir William: You are satisfied as far as your experiment goes that it is applicable to this kind of structure?—So we believe, although we have very little experience of this type of structure, but I see no reason to doubt its application to this sort of structure. I personally would not take a lower figure than 9 to 1 because it would be an exceedingly dangerous practice at the moment.

Sir Arnold added, "We have a good deal of experience of spars, booms, joints and wing-like structures, all of which support the contention that it would not be wise to work outside this margin at the moment. We get ratios of 9 to 1 with things like main wing spars where the stress level is rather lower than in these cabins. There is not the slightest doubt about this 9 to 1 and I do not think anyone is seriously misled by accepting that it exists."

Sir William: The difficulty in my mind is this. You did a test on a structure, Yoke Uncle, under these conditions and it failed in fatigue with an alternating load at roughly 3,000 applications of pressure. If we accept, for the purpose of this question, the idea that two aircraft in flight fail for the same reason on 1,000 pressurisations, which is roughly the number, then there is a problem of how we regard the total evidence. It has been suggested in evidence that tests on Yoke Uncle, because they were tests on the ground under controlled conditions, should be regarded as an average. I cannot see any evidence whatever that that is an average, meaning that the number of applications of load at which it failed is half-way in the picture drawn on the sort of diagram you produce, namely that the one with the longest life would fail at three times that, namely 9,000, and the one with the shortest life fail at 1,000.

Sir Arnold said that they did not rely on Yoke Uncle being an average specimen. If it were an average specimen that explained the disasters. It might even be stronger than average.

Sir William: The only proof that Yoke Uncle is average is the high probability that Yoke Peter and Yoke Yoke were at the bottom end, and of that there is no absolute evidence. It is only an assumption.

The chairman: Are you saying the two that did crash, Yoke Peter and Yoke Yoke, were below the watermark on the line? If that was so the reasonable inference might be that at about 9,000 hours might be the average, but even if some lower watermark might exist your conclusion would still be the same, that they were in the 10-to-1 ratio, and you would say the crashes at 1,000 applications, which did occur, were corroborative evidence of the conclusions of the cause of such accidents?

Sir Arnold: I find no inconsistency between the failures caused, we think, by fatigue on Yoke Peter and Yoke Yoke and the failure on Yoke Uncle in the tank.

That concluded the evidence before the Inquiry.

FINAL SPEECHES

The first of the final speches was made by Mr. M. A. L. Cripps for the Ministry of Supply, who said: "It is clear that there has been no error of commission or omission on the part of the Royal Aircraft Establishment. The Ministry does not suggest any shortcomings on the part of anybody else and, as I understand it, there has been no question of shortcomings by the Ministry."

He concluded: "I hope the court will think that there is a very bright future for the Comet, which is a product of co-operation and is now well on its way to beat the world. I hope this Inquiry will contribute effectively to maintain the high standard of efficient workmanship and safety for which the aircraft of this country have been so long well known."

The Inquiry adjourned until Thursday.

On Thursday, November 18, Mr. D. A. Grant, counsel for the Ministry of Transport and Civil Aviation, concerned with whether the Minister of Transport was properly advised in continuing the Comet services in March, 1954, said: "If the Minister had been advised that the condition of the Comet aircraft was such as has now been given in evidence the service would not have been resumed. The cause of the accident is said to be that this type of aircraft is so constructed and designed that, unfortunately, after a short life in its normal flying conditions the aircraft can fail in such a way that it would cause an explosion in the cabin and destroy the aircraft. If that had been brought to the knowledge of anybody, the Minister would certainly not have allowed this aircraft to fly. That, of course, would have been the case, not only for the Minister but for those who advised him. Had B.O.A.C., de Havilland's, or anyone, realised the condition of the aircraft was such, no one would have allowed it to fly."

In conclusion, Mr. Grant said the Minister would like to assure the public that he would consider all the defects disclosed in the Inquiry before the Comet was allowed to fly again.

Mr. J. W. Shaw, for the relatives of deceased passengers, said that while the cause of the accident to Yoke Peter appeared to be the disruption of the fuselage, the question really was what caused it.

He recalled that the early evidence at the Inquiry made it appear that the Farnborough investigations had produced the answer, which, as he understood it, was that the general level of stresses was so high that the aircraft was liable to disrupt at any moment.

"Having heard the subsequent evidence it does not appear to be as clear as that," said Mr. Shaw. "I am fortified in questioning the Farnborough report by the doubts raised by Mr. Tye (a witness for the Air Registration Board). He was unable to put forward any alternative explanation, but that does not mean that one must necessarily accept the explanation that has been put forward."

After referring to differences of opinion regarding tests carried out to ascertain the stress around cut-outs, Mr. Shaw said: "If there is scope in the system for misunderstanding between the Air Registration Board and de Havilland's or any other manufacturer on the basis on which they are designing an aircraft, it certainly looks as if some alterations should be made in the procedure so that it is not possible in the future. But it does seem a most dangerous position that the Air Registration Board should have granted a Certificate of Airworthiness, on which the public and the operators rely, on a misunderstanding about information which was given to them and which was part of the build-up on which the certificate was granted."

Mr. Shaw then referred to the de Havilland Company not ascertaining fatigue and the chairman said: "They have said that their calculations and design had no special regard for fatigue because they thought any possibility of fatigue would be taken care of."

Mr. Shaw said the Air Registration Board's requirements showed a clear warning of the danger of fatigue as early as 1948 and it was surprising that it was not considered a serious problem until 1952.

Mr. Shaw said that it was known that there were three cracks in the Comet YP, one in YU, and one in YY. He said: "How many there were in other aircraft we don't know but the fact that there were some should have driven them back again to inspect these aircraft and possibly to have revealed potential dangers. If this had applied to all of them one does not know what it would have revealed."

He asked if it were necessary to have "doubler plates," around vital areas such as hatches, which prevented inspection of the skin underneath.

The chairman, Lord Cohen, remarked: "All manufacturers try to provide inspectable parts but there are sometimes no means of doing so."

Mr. McCrindle referred to the salvaging of wreckage from Yoke Peter, and said that the prevalent view had been that a substantial amount of the wreckage would not be recovered and in addition that which was recovered would not be of much use because of the effect of sea water on it. He suggested that with the results they now had, of wreckage recovered with so little effect from sea water, that fact should be circulated to all concerned.

The chairman suggested that anyone interested must be fully informed as a result of what the Inquiry had revealed.

NOTIFICATION OF CRACKS

Mr. McCrindle referred to manufacturing cracks and said that it was not suggested they were in any way directly responsible for the accidents, but the significance of them was that they had occurred and he was pleased to know that the system under which they might have occurred had now been modified. He felt, too, that those who were concerned, and who were going to certify the airworthiness of an aircraft, should know of any cracks whether they were covered by a concession note or not.

The chairman: "What you are saying is that the operator's attention should be called to them?"

Mr. McCrindle said that in relation to such things as cracks in a pressurised area, all were agreed that they were very serious indeed and in future it would be beneficial if manufacturing processes which caused cracks, and cracks themselves, if they arose from some other cause, should have specific attention drawn to them. This, he suggested, should be for the Air Registration Board and the operators.

The chairman: "Surely manufacturing cracks in dangerous areas should not be allowed."

Sir Hartley Shawcross said no one wanted manufacturing cracks, and stresses must be reduced so that there were no such cracks. It would not be the Company's general practice to issue something which required attention later on. Sir Hartley added that

concessions were only issued for something which would not interfere with the success of the aircraft.

Mr. McCrindle also spoke of calculations and strain-gauge tests, and said that if these had been done at the appropriate part round the cut-outs it might have been that they would have found a stress level which would have caused them to think again.

The chairman: You mean they would have found the stress was too high ?—Yes.

Mr. McCrindle said that either the Farnborough tests were right in showing a high stress round the cut-outs, or, if they were wrong, strain-gauge readings would have been found sufficiently high to give cause for concern. Of course, he said, the de Havilland Company were entitled to rely on the very many tests they did during their proof testing.

Counsel then referred to the power-operated control in the Comets and said " This is another matter about which there is a difference of opinion. We have been told by Mr. Bishop that on the Comet III the break-out force of this power-operated control has been adapted and reduced and the de Havilland Company test pilots are very pleased with it, so it would seem a step has been taken in the right direction. There is a sufficiency of adverse comment on the break-out force associated with this power-operated control to give cause for concern and give rise to relief that de Havilland's have in future chosen to modify it in Comets.

" This power-operated control is described in the Farnborough report as a most undesirable feature of the aircraft, and the Calcutta report says special consideration should be given to whether it was a good thing or not."

INDEPENDENT INSPECTION BODY

Mr. McCrindle, in concluding his speech, suggested that it might be a good thing if an independent inspection body could be set up on the lines of Lloyd's Inspection Department for issuing certificates of seaworthiness, and such an inspectorate could operate in conjunction with the Air Registration Board in issuing certificates of airworthiness.

The chairman: We should have to be very careful about disturbing the system which has gone on as long as the aircraft industry has existed.

Mr. McCrindle: I appreciate that, but I have put it forward because those instructing me feel fairly strongly about this. I appreciate your comments and take it no further than that.

The Inquiry adjourned until Friday.

On Friday Mr. T. Humphrey Tilling, appearing for the Navigators and Engineer Officers Union, told the court he had assembled what amounted to a " minority report " from the evidence, which might result in the feeling that someone had done something they should not have done.

He gave the court two possibilities of the origin of the failure of the pressurised cabin in Yoke Peter. The first he called " the Farnborough site "—the starboard rear corner of the A.D.F. window, and the second the port forward corner of the window, with the possibility that it might have been done by undetected fatigue.

Mr. Tilling said manufacturing cracks did not contribute to the disaster directly but there might have been incipient cracks and no one could tell whether they were at this window.

Sir Hartley Shawcross, for the de Havilland Company, interrupted Mr. Tilling to say: " There is no minority opinion on these matters, except in so far that alternatives have been put forward in cross-examination." Every witness had said that in his opinion the origin of the failure was on the starboard side.

When Mr. Tilling was dealing with cracks the chairman said: " I think it was the general opinion that manufacturing cracks were a source of danger when they were in a restricted area."

Sir Hartley Shawcross: I don't want it thought for a moment that manufacturing cracks should remain for ever.

Mr. Tilling referred to the question before the court of whether the Comet should have flown again after Elba, and said it seemed from the " minority point of view " that, had it been known after Elba that there were either manufacturing cracks or a general stress level of 70 per cent, the evidence was that the Comet would not have flown.

So far as the de Havilland Company were concerned, he suggested, the question was whether after Elba they should have reported those manufacturing cracks, or made further calculation, or informed the Air Registration Board that the original calculations were not for fatigue purposes, or should have taken further strain-gauge tests.

TESTS ON UNCONVENTIONAL AIRCRAFT

Mr. Tilling said that it had been suggested that novel features in aircraft were sometimes ahead of the existing requirements of the Air Registration Board for certification purposes. The Comet was a case in point. He added: " My suggestion is that if in the future some such new aircraft or novel feature in an aircraft, of which scientific opinion holds the view that not a very great deal is known about the new feature or aircraft, the A.R.B. should be empowered in this case to send that aircraft or that novel feature either to Farnborough or Boscombe Down as an independent testing organisation acting on the part of the A.R.B. The A.R.B. should be empowered to say that such testing should be financed from the public purse.

" The number of occasions on which it would be necessary would be very few indeed but it would standardise the testing of these new features in aircraft."

He said that he also suggested that during the time the manufacturing firm was engaged with a new type of aircraft the firm's inspectors should become the employees of the A.R.B. The A.R.B. would have the power of dismissal and therefore the inspectors' loyalty would be directed to the A.R.B.

Another " fear " of his clients was that with much delicate technical apparatus in the aircraft to be dealt with in a very much shorter time, unless really proper accommodation or stations are provided for the crew they cannot feel absolutely confident that they will be able to look after everything they should.

REDUX BONDING

Mr. J. Whitford, representing Aero Research Limited, discussing Redux metal adhesive, said there were three questions: whether it caused the accidents, whether it was a factor in causing the accidents, and, if the answer to both those was in the negative, should any recommendation be made about using such substances in aircraft in the future.

His clients were most anxious that the fullest consideration should be given to the matter and the fullest investigation should be made. It appeared that there was some concern in the public mind, according to various papers, that aircraft of that character flying at great height and pressurised, should be stuck together with glue.

Mr. Whitford said glue was not used for the first time in the Comet. It was used in 1945 by the de Havilland Company in Dove aircraft in the same way as in the Comet, to attach stringers to the fuselage, and had been used in many other aircraft, including high-speed aircraft

Mr. Whitford referred to the evidence of Mr. Jablonsky who, he said, had pointed out that extremes of temperature would affect adhesion so far as this glue was concerned. He had also said that pressure difficulties would create a " peeling force " in connection with the glue. Mr. Jablonsky had postulated a theory which was in complete conflict with the Farnborough theory. It was impossible on the evidence to accept Mr. Jablonsky's theory regarding Yoke Peter because it had been said it did not fail through that.

Mr. Whitford said it was abundantly established that Redux was not the cause, or a factor in causing the accidents and nothing had been disclosed in the Inquiry to make necessary any recommendation about the future use of this process.

Sir Hartley Shawcross also referred to the adhesive when he began his address, referring to many tests that had been made without finding a single failure which led anyone to regard the adhesive as anything but good. There was no case of any failure causing any significant result.

Sir Hartley said: " The best thing we can do in this Inquiry is to find out all the facts and find out what measures can be taken in future to deal with the dangers that have come to light."

Referring to the Comet he went on: " It has been submitted to a testing, an examination and a scrutiny, the like of which has never been brought to any other aircraft in the whole history of aeronautics. To the surprise of everybody it has been found to possess the one vital fault—this proneness to fatigue in the pressure fuselage. Beyond that it has been established to be an aircraft of quite remarkable excellence in design and workmanship. Some day—one hopes in the not too distant future—Comet aircraft will be in the air again. But when they are there will be no other aircraft in use that has been submitted to a greater examination. They will go in the air with the very hall mark of safety."

REMARKABLY ENGINEERED AIRCRAFT

He asked that the Court, when they considered the " grave problems " that had arisen out of the Inquiry, to bear all this in mind as a general background and to remember that the Comet was a " remarkably engineered aircraft with a background of which any aircraft engineer would be proud."

Sir Hartley said that the fact that the Yoke Peter disaster was caused by fatigue might to some lay people appear to have been very simple and very obvious. In fact, the truth was that it was nothing of the kind. Evidence had been given that the original assumption was that fatigue was *not* the cause of the accident. The tank test was decided on not because it was thought the cause was fatigue but because it was thought that the tank test might pick up all sorts of possible troubles and weaknesses of another kind. At that time the Royal Aircraft Establishment knew a great deal about the Comet. It was significant that, even with that knowledge and information, Dr. Walker had said that in the state of scientific knowledge then fatigue was incredible.

" But fatigue it must, in fact, have been and all the experts, with the exception of Mr. Tye and Mr. Jablonsky, have no doubt about it. I shall proceed on the basis that it was fatigue and consider the question of where it originated and whether cracks had anything to do with it."

On the question of cracks there were two points; one—did they have anyting to do with these two disasters; and, two—what was the general position on cracks and their effect on safety.

" My first task will be to show that they have nothing to do with these disasters. I have never suggested they are desirable things and I shall have some comments about them; but I shall say they have nothing to do with this disaster."

He said that he would ask the Court to consider the question of cracks in a more general way and he was himself saying that the de Havilland Company would not let any aircraft go out with a crack in it knowing what they know now.

At this stage the Inquiry adjourned until Monday.

To be continued

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SYMPOSIUM ON PROTECTION OF STRUCTURAL STEEL

Arrangements have been made by the Corrosion Group of the Society of Chemical Industry to hold a symposium on " The Protection of Structural Steel " at the Institution of Civil Engineers, Great George-street, London, S.W.1, on Thursday and Friday, March 31 and April 1, 1955.

Papers are expected from authors in Britain, the United States, France, Holland, Belgium and Sweden. Those based on practical experience will deal with protection by sprayed metal coatings, current painting practice for steel structures in the United States, the painting and protection of steel structures in Britain, protection problems in chemical plants, the preservation of steel in gasworks, and factors in the protection of steel in steelworks. In addition, there will be a number of papers based on comparative tests of paints and protective coatings.

Applications to attend the symposium should be addressed to the honorary secretary of the Corrosion Group, Mr. S. C. Britton, Tin Research Institute, Fraser-road, Perivale, Greenford, Middlesex.

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AIR POLLUTION

New York Congress in 1955

Among the events being arranged by the American Society of Mechanical Engineers in celebration of the 75th anniversary of its formation is an international congress on air pollution, which will be held at the Hotel Statler, New York, on Tuesday and Wednesday, March 1 and 2, 1955. Participation in the congress by Europeans is being specially encouraged and it is expected that delegates from Britain, Holland, France, Germany and Portugal will be present.

Subjects to be discussed will include gaps in knowledge relating to air pollution, the role of sulphur gases, the recovery of sulphur dioxide from coal-combustion stack gases, the removal of sulphur dioxide from power-plant stack gases, and the world supply of sulphur.

A leading feature of the congress will be the delivery of the Calvin W. Rice Lecture by Sir Hugh Beaver, M.I.C.E., chairman of the governmental committee set up in July, 1953, to examine the nature and causes of air pollution in Britain and the efficiency of present preventive measures.

Further information may be obtained from the Committee on Air Pollution Controls, American Society of Mechanical Engineers, 29 West 39th-street, New York, U.S.A.

THE IRON AND STEEL INSTITUTE

Business at the Autumn General Meeting

The autumn general meeting of the Iron and Steel Institute was held in London on Wednesday and Thursday, November 17 and 18. On the morning of the first day, the President, The Hon. R. G. Lyttelton, who occupied the chair, referred to the recent deaths of four old members, namely, Mr. Seth Smith Somers, who had joined the Institute in 1896, Mr. James Campbell, a member since 1897, Mr. George Baker, O.B.E., M.I.Mech.E., who had been elected in 1902, and Mr. John Charles Willis Humfrey, O.B.E., B.A., M.Sc., M.Eng., who had become a member in 1903. He subsequently announced that the 1955 annual general meeting of the Institute would be held on Wednesday and Thursday, April 27 and 28, and the autumn general meeting on Wednesday and Thursday, November 16 and 17, both meetings to take place in London. In June, 1955, a joint metallurgical societies meeting would be held in Europe. The British section of the meeting, which would be held jointly by the Institute with the Institute of Metals, the American Institute of Mining and Metallurgical Engineers and the American Society for Metals, would be from June 1 to 7, and H.R.H. The Duke of Edinburgh had agreed to become Patron of this. The meeting would then continue in Germany, Belgium and France from June 8 to June 18.

A special meeting of the Institute would be held in Scunthorpe, by invitation of the Lincolnshire Iron and Steel Institution from Wednesday to Friday, October 12 to 14, 1955. In 1956, a special meeting of the Institute would be held in Paris. The Council had accepted an invitation issued by the Chambre Syndicale de la Sidérurgie Française, in conjunction with the Société Français de Métallurgie to hold such a meeting, which would take place probably in June.

The President's final pronouncement was to propose, on behalf of the Council, that Sir Charles Bruce-Gardner, Bt., M.I.MechE., be nominated for election as President, to take office at the annual general meeting in 1955 and to serve for one year.

CHANGES IN THE COUNCIL

The Secretary then announced the changes in the Council which had taken place since the annual general meeting held in May, 1954. Mr. D. F. Campbell had been appointed a vice-president and Mr. Berndt Grönblom and Mr. Evert Wijkander, honorary vice-presidents. Several honorary members of Council had been elected to serve during their periods of office in various spheres. They were Mr. W. M. Larke, chairman of the Institute's Engineering Committee, in place of Mr. C. H. T. Williams (Mr. Williams remains on the Council as a member); Mr. H. M. Morgan, President of the Cleveland Institution of Engineers, in place of Mr. F. Kennedy; Mr. J. J. Beese, President of the Ebbw Vale Metallurgical Society, in place of Mr. A. W. Ellis; Mr. C. E. Burrell, President of the Leeds Metallurgical Society, in place of Mr. H. D. Ward; Lieut.-Comdr. G. W. Wells, President of the Lincolnshire Iron and Steel Institute, in place of Mr. W. L. James; Mr. G. T. Callis, President of the Liverpool Metallurgical Society, in place of Mr. H. J. Miller; Mr. C. I. F. Mackay, chairman of the Newport and District Metallurgical Society, in place of Mr. T. G. Grey-Davies, and Professor H. O'Neill, President of the Swansea and District Metallurgical Society, in place of Mr. D. L. Blewett.

In addition to the above, three vice-presidents and five members of Council were due to retire at the next annual general meeting but were eligible for re-election. The vice-presidents were Mr. G. H. Latham, Mr. J. Sinclair Kerr, and Dr. H. H. Burton. The members of Council were Dr. J. W. Jenkin, Mr. W. F. Cartwright, Mr. F. H. Saniter, Mr. T. Jolly and Mr. R. A. Hacking.

Since the last general meeting of the Institute, three awards of Andrew Carnegie Scholarships had been made, namely: £410 to Mr. C. J. Ball of Queen's College, Cambridge, to assist research on the "Plastic Deformation of Metals"; £350 to Mr. P. R. Vaughan Evans, of University College, Swansea, to assist research on "The Mechanical Properties and Internal Stress of Various Strip Steels after various Isothermal Treatments"; and £50 to Mr. J. Wilcock, of Liverpool University, to assist research on "The Influence of Manganese, Sulphur and the Sulphur to Manganese Ratio on the Kinetics of First-Stage Graphitisation."

At the conclusion of the final business, the meeting turned to the presentation and discussion of papers. These will be reported in subsequent issues.

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OBITUARY

MR. A. D. CONSTABLE, O.B.E.

We regret to record the death of Mr. A. D. Constable, which occurred at Weybridge, Surrey, on Friday, November 12. He was 79.

Arthur Douglas Constable was born on April 19, 1875. He received his technical education at the Central Technical College, London, under Professor W. E. Ayrton and obtained the diploma in electrical engineering. In 1895, he joined the staff of the India Rubber, Guttapercha and Telegraph Works Company, Limited, with whom he was engaged on submarine cable testing, both on shore and at sea. In 1898, he obtained an appointment as shift engineer at the Croydon Electricity Works and later served as public lighting engineer. After a short time as chief assistant electrical engineer with the Chatham and District Light Railways Company, he was appointed assistant electrical engineer in H.M. Dockyard, Portsmouth, in 1903.

Shortly before this time, Mr. C. H. Wordingham had become superintending electrical engineer at the Admiralty, being charged with equipping the dockyard shops and installations with the electric drive and modernising the plant on warships. Constable assisted in this work, first as electrical engineer at H.M. Dockyard, Bermuda, and then in a similar position at H.M. Dockyard, Gibraltar. He held the latter position until his transfer to the Admiralty in 1913 as electrical engineer. He became Assistant Director of Electrical Engineering in 1918, Deputy Director in 1922, when he was mainly engaged on problems of design, and Director in 1934, a position he held until his retirement in 1937. He was then appointed an Officer of the Order of the British Empire.

Mr. Constable was elected an Associate of the Institution of Electrical Engineers in 1898. He was transferred to the class of Associate Member in 1902, and to that of Member in 1909. He was also a Fellow of the City and Guilds Institute.

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ELECTRICITY IN OCTOBER

During October, 1954, 5,661 million kWh were sold by the British Electricity Authority to the Area Boards. This was an increase of 6·9 per cent. over the figure for October, 1953. When corrected for the weather, which was warmer than a year earlier, the increase was, however, 10·4 per cent. The amount of electricity sent out by the Area Boards was 5,540 million kWh, while 121 million kWh were supplied direct by the Central Authority. The increases in the amounts sent out, compared with the corresponding figures in 1953, were 7·1 per cent. in the "mainly industrial" areas and 5·1 per cent. in the "mainly non-industrial" areas.

NON-DESTRUCTIVE INSPECTION

New Society Formed

In view of the greatly increasing application of non-destructive testing in all branches of the engineering industries a Society of Non-Destructive Inspection has been formed in Great Britain to assist persons responsible for the utilisation of examination methods of this type. The new Society is concerned with the promotion of radiographic, magnetic, acoustic and other methods of non-destructive inspection and its main object is the free and informal interchange of information and experience between those engaged upon the development, control and use of non-destructive testing equipment and techniques. Its membership is drawn from a wide range of engineering industries and includes persons engaged in aircraft construction, atomic-energy research, shipbuilding, and the electrical, transport and other industries.

The honorary chairman of the new Society (or S.O.N.D.I., as it is also called) is Mr. C. Croxson, the honorary secretary is Mr. C. C. Bates, the honourary treasurer, Mr. L. Mullins, and the members of the committee, Mr. F. C. Cocks, Mr. C. A. Kershaw and Mr. R. N. Thompson. The headquarters are at Duncan House, Dolphin-square, London, S.W.1.

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DEVELOPMENT OF AUTOMATIC FACTORIES

In view of the many technical, sociological and managerial problems involved in the development of automatic factories, a special committee has been set up by the Institution of Production Engineers, under the chairmanship of Major-General Kenelm Appleyard, C.B.E., to make arrangements for holding a national conference.

Particular attention will be paid to the impact on smaller factories of automatic methods of production. The conference, which will be held at Margate from Thursday, June 16, to Sunday, June 19, 1955, is likely to be of interest to a wide range of engineers, scientists, educationists and managers. Preliminary programmes are expected to be ready in the near future and communications on the subject should be addressed to the secretary of the Institution, 10 Chesterfield-street, London, W.1.

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INSTITUTION OF ELECTRICAL ENGINEERS

Christmas Lecture

"Nuclear Power: Electricity from Uranium" has been chosen as the subject for the 1954 Christmas lecture of the Institution of Electrical Engineers, for delivery to older schoolchildren. The lecture will be given by Dr. T. E. Allibone, D.Sc., F.R.S., M.I.E.E., at the Institution building, Savoy-place, Victoria-embankment, London, W.C.2, on Thursday, December 30, commencing at 3 p.m., and will be repeated on Friday, December 31, at the same time.

This is the ninth year in which the Institution has organised Christmas lectures for juveniles and an effort has been made to evolve a suitable technique for their delivery, so that they may be of the maximum interest and benefit.

No charge is made for admission and applications for tickets should be sent to the secretary of the Institution at the above address.

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Dr. F. J. Wallace, author of the article "Wave Action in Diffusers for Pipe Systems" (ENGINEERING, October 22, page 524) wishes us to make it clear that the work on which the article was based was carried out in the Department of Mechanical Engineering of the University of Birmingham. In addition, he has pointed out that the designation of the abscissæ in Fig. 5 should have been $\frac{u_e}{a_0}$ and not $\frac{u_0}{a_0}$.

CONTRACTS

Electrical Equipment for Rolling Mill. Dorman, Long (Steel) Ltd., Middlesbrough, have placed a contract for electrical plant and control gear valued at £250,000 with the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2. The order covers electrical equipment for the auxiliary drives of a combined universal beam and heavy-section rolling mill for the new works at Lackenby, and includes nearly 6,000 h.p. of mill-type motors. Ten synchronous motor-generator sets will provide the direct-current supplies for the mill motors. The control gear, which embodies the firm's control exciter system, includes five switchboards of the flat-back contactor type.

Diesel Mechanical Shunting Locomotives. The Eastern Region of British Railways announce that contracts have been placed for the supply and delivery of 37 Diesel mechanical shunting locomotives. Nine locomotives will be supplied by the DREWRY CAR CO. LTD., City Wall House, Finsbury Pavement, London, E.C.2; two by RUSTON AND HORNSBY LTD., Locomotive Division, Boultham Works, Lincoln; ten by ANDREW BARCLAY, SONS & CO. LTD., Caledonia Works, Kilmarnock; and 16 by the HUNSLET ENGINE CO. LTD., Hunslet Engine Works, 125 Jack-lane, Leeds 10.

Power Plant Equipment. Contracts have been placed by the British Electricity Authority, during October, for power-station, transforming-station and transmission-line equipment amounting, in the aggregate, to £3,747,776.

The principal contracts include: for Brighton "B" power station: two 72 MVA 34·8/11·6 kV generator transformers, with the ENGLISH ELECTRIC CO. LTD.; for Brimsdown "B" power station, near Enfield: 33 kV and low-voltage cables and accessories, with ABERDARE CABLES LTD.; for Bold "A" power station, St. Helens: two 36 MVA 11·8/33·4 generator transformers, with the METROPOLITAN-VICKERS ELECTRICAL CO. LTD.; for Portobello power station, Edinburgh: circulating water pumps, pipework, valves and strainers, with DRYSDALE & CO. LTD.; for Agecroft substation, Salford: 132-kV, 3,500 MVA switchgear, with the METROPOLITAN-VICKERS ELECTRICAL CO. LTD.; for Penwortham substation: 275 kV 7,500 MVA switchgear, with FERGUSON PAILIN LTD.; for Rochdale substation: site and foundation works, with LEONARD FAIRCLOUGH LTD.; for Warrington substation: modifications to 132 kV switchgear and equipment, with FERGUSON PAILIN LTD.; and for Dalmarnock substation: 132 kV 2,500 MVA switchgear, with the METROPOLITAN-VICKERS ELECTRICAL CO. LTD. Standardised indication and telephone equipment has also been ordered from the GENERAL ELECTRIC CO. LTD., and STANDARD TELEPHONES AND CABLES LTD., for various grid control areas.

Tractors and Implements. Two important contracts for tractors and implements for South American countries have been secured by DAVID BROWN TRACTORS (ENGINEERING) LTD., Meltham, Yorkshire. A first shipment of 120 machines has left Liverpool for Bolivia, and further supplies will be following shortly. The Bolivian Government has chosen three models. Two are wheeled machines and the other is a tracklayer and all have direct-injection Diesel engines. Of the two wheeled models, one, the 30D, is a four-cylinder general purpose machine having a low fuel consumption and the other, the 50D model, is the largest of the firm's wheeled tractors, has a six-cylinder 50-b.h.p. engine and is primarily designed for use with heavy-capacity trailed implements. The third, tracklaying, machine is the firm's 50TD six-cylinder 50-b.h.p. model, intended for multi-furrow ploughing at fast speeds.

The second contract for South America covers 84 tractors and a selection of implement and spare parts and is for Chile. Its value is £100,000.

Airliners. The West African Airways Corporation have placed an order with the DE HAVILLAND COMPANIES, Hatfield, Hertfordshire, for three Heron Series 2 aircraft, to be delivered early in 1955. The aircraft will be used in the extensive network of local services operated by the Corporation, a subsidiary concern of B.O.A.C., in Nigeria, the Gold Coast and along the West African coast from Dakar to the Cameroons.

Coke-Oven Plants. THE WOODHALL-DUCKHAM CONSTRUCTION CO. LTD., Woodall-Duckham House, 63-77 Brompton-road, London, S.W.3, have received from the South African Iron and Steel Industrial Corporation Ltd., two orders for coke-oven plants, the approximate total value of which amounts to £1,750,000. One plant is to be built at the Vanderbijl Park Works and the other at the Pretoria Works.

PERSONAL

MR. JEAN MONNET has decided not to stand for re-election as President of the High Authority of the European Coal and Steel Community, Luxembourg, at the expiry of his term of office on February 10, 1955.

MR. F. A. RAYFIELD, M.I.C.E., M.I.Mun.E., the senior divisional engineer in the chief engineer's department, London County Council, County Hall, S.E.1, has been promoted to be deputy chief engineer in succession to MR. FORBES JACKSON, M.I.E.E., M.I.Mech.E., who as stated on page 651 of our issue of November 19, retired on November 7.

MR. F. J. COLVILL, C.B.E., Engineer Surveyor-in-Chief of the Marine Survey Service, Ministry of Transport and Civil Aviation, Berkeley Square House, London, W.1, is retiring on February 11, 1955. He will be succeeded by MR. F. J. WELCH who has been deputy Engineer Surveyor-in-Chief since 1950. Captain J. C. TAYLOR, C.B.E., professional officer (Chief Nautical Surveyor) of the Marine Survey Service, is retiring on March 31, 1955. He will be succeeded by CAPTAIN J. H. QUICK, O.B.E., who has been principal examiner of masters and mates since 1945.

MR. J. N. DEAN has been appointed chairman of the Telegraph Construction and Maintenance Co., Ltd., Hitherto Mr. Dean was deputy chairman. LORD COLGRAIN has been elected a director to fill the vacancy caused by the recent death of his father, the 1st BARON COLGRAIN.

GENERAL SIR WILLIAM D. MORGAN, G.C.B., D.S.O., M.C., chairman of Siemens Brothers & Co., Ltd., and MR. JOHN INNES, C.B., director of the Telegraph Construction and Maintenance Co., Ltd., have been elected directors of Submarine Cables Ltd.

The technical staff of Short Bros., & Harland Ltd., Belfast, will now be divided into four groups, namely, structures, project and aerodynamics, aircraft design, and Castlereagh (guided weapons and research departments) under the overall direction of MR. DAVID KEITH-LUCAS, director and chief designer. MR. R. BOORMAN, previously deputy chief engineer, is now appointed chief structural engineer; MR. C. D. HATTON becomes assistant chief engineer (aircraft); MR. F. H. ROBERTSON becomes chief project designer; MR. K. L. C. LEGG, formerly assistant designer, structures, becomes structural development engineer and MR. F. P. YOUENS, formerly chief aerodynamicist, is now advance projects engineer.

MR. L. H. JACKSON and MR. J. I. CALCOTT have relinquished their positions on the board of Coventry Radiator and Presswork Holdings Ltd. MR. H. R. MOORE and MR. H. HEATH have been elected to fill the vacancies.

DR. E. J. HOLMYARD, M.A., M.Sc., F.R.I.C., has retired from the editorship of *Endeavour*, the quarterly international scientific review published by Imperial Chemical Industries Ltd., Millbank, London, S.W.1. His successor is DR. TREVOR I. WILLIAMS, M.A., B.Sc., F.R.I.C., who has been deputy editor since 1945.

MR. K. H. BISHOP, M.I.Ex., general sales manager of A. A. Jones & Shipman Ltd., Narborough-road South, Leicester, MR. F. W. BROOKS, works accountant, and MR. A. E. POLLARD, assistant to the works director, have been elected directors of the company.

MR. J. C. MILNE, M.I.E.E., technical director of the Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton, has been appointed managing director in succession to the late MR. W. M. B. FURNISS.

MR. C. K. TURNER-HUGHES, A.F.R.Ae.S., has been appointed commercial manager of the aircraft electrical division of the Plessey Co., Ltd., Ilford, Essex.

MR. A. H. PENDREE has been appointed general sales manager and MR. M. S. MEYER, director of sales to the Goodyear Tyre and Rubber Co. (Great Britain) Ltd., Wolverhampton. MR. DONALD GOW has been made financial director.

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BUSINESS CHANGES

HOLDEN AND BROOKE LTD., Sirius Works, Manchester 12, announce that they have moved their York office from Peasholme House, St. Saviour's Place, to 2 St. Sampson's-square. The telephone number remains the same: York 4583.

HEENAN & FROUDE LTD., Worcester, who have had a majority holding in BRITISH ORGANIC PRODUCTS, LTD., 7 Old Bailey, London, E.C.4, since July, 1953, have now acquired the balance of the issued capital. MR. H. A. S. GOTHARD, MRS. M. H. GOTHARD and MR. A. H. A. CARDEW have resigned from the board, and MR. W. BRYAN DRAPER, managing director of Industrial Waste Eliminators Ltd., has been appointed a director of British Organic Products Ltd. The board now consists of MR. F. J. FIELDING (Chairman), MR. A. C. HAYES, MR. A. H. LANGFORD and MR. W. B. DRAPER. It is intended to carry on the business as a wholly-owned subsidiary company of Heenan & Froude Ltd.

F. C. ROBINSON & PARTNERS LTD., makers of electronic controls and instruments, are to remove from 287 Deansgate, Manchester 3, to larger premises at 122 Seymour-grove, Old Trafford, Manchester 16, as from December 13. (New Telephone No.: Chorlton 5366.)

THE GOODYEAR TYRE AND RUBBER CO. (GREAT BRITAIN) LTD., Wolverhampton, have appointed SOUTHERN INDUSTRIAL RUBBER LTD., 1 High-street, South Norwood, London, S.E.25, to be distributors of their products in Kent, Surrey, Sussex, Hampshire, Berkshire, the southern portion of Middlesex and Buckinghamshire, and the S.E., S.W., and W. postal districts of London.

GENT & CO. LTD., Faraday Works, Leicester, have appointed Henry Tatton & Son Ltd., 24-30 Rose-street East, Hanover-street, Edinburgh 2, as their agents for their controlled electric-clock systems, time recorders and programme instruments. Messrs. Tatton have now also taken over premises at 20 Blythswood-street, Glasgow, C.2, formerly occupied by the late MR. W. B. MARTIN who was agent for Gent & Co. in Scotland.

LEO COMPUTERS LTD., a wholly-owned subsidiary company of J. Lyons & Co. Ltd., have been formed to carry on the business of manufacturers of, and dealers in, all forms of electrical or automatic computers and office machinery and automatic control equipment.

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MACHINES FOR THE TOOLROOM

An exhibition of machine tools having a particular application to toolroom work has been arranged in London by Burton Griffiths and Co., Ltd., Mackadown Lane, Kitts Green, Birmingham 33. The exhibits include representative models from the range of engraving, die-sinking, profiling, tool-milling and universal tool-grinding machines made by F. Deckel, of Munich, Germany, and a new "Sparcatron" machine for cutting hard metals by the electric spark technique. Details of the machines exhibited are given elsewhere in this issue.

The exhibition, open from Monday, November 22, to Saturday, December 4, is at the London showrooms of the B.S.A. Tools Group, of which Burton Griffiths and Co., Ltd., are members, 93 Albert Embankment, London, S.E.11.

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MECHANICAL ENGINEERING AS A PROFESSION

Conference on Recruitment

A conference on the subject of "Recruitment to the Mechanical Engineering Profession" is being arranged for headmasters, careers masters and science teachers of public and grammar schools by the Institution of Mechanical Engineers, and will be held at the Institution on Tuesday, December 7, at 3.30 p.m. Leading members of the Institution will speak on the scope and opportunities in mechanical engineering at professional level for boys with a public- or grammar-school background. Sir Ewart Smith, a vice-president of the Institution and technical director of I.C.I., Limited, who is to occupy the chair, will be among the speakers; others will include Mr. T. A. Crowe, M.Sc., also a vice-president and the chief managing director of the North British Locomotive Company, Limited, and Major General S. W. Joslin, C.B., C.B.E., M.A., of the U.K. Atomic Energy Authority, who is a Member of Council of the Institution.

On the same day at 6.45 p.m., the Education Group of the Institution are holding a discussion meeting. The subject, "Recruitment from Secondary Grammar Schools," will be introduced by Professor S. J. Davies, D.Sc., and representatives from schools, colleges, and industry are invited.

Book Reviews

THE PROSPECT BEFORE US

The Challenge of Man's Future. By HARRISON BROWN. *Martin Secker and Warburg, Limited, 7 John-street, Bloomsbury, London, W.C.*1. (21*s.*)

Industrial civilisation, based on machinery and science, has caused an enormous growth in world population and is consuming natural resources at a rapid and cumulatively growing rate; yet only one-fifth of the world's population lives in a fully industrialised society and another fifth lives in a transitional state. The rest of the world continues in almost entirely agrarian societies similar in techniques and, to some extent, in social organisation to those of England before the Eighteenth Century. If the under-developed areas were able to raise their living standards to those of the industrialised countries, the demand for food, sources of energy and minerals would be so great that man could no longer exist on the earth unless he brought into play the most advanced scientific processes for the extraction of raw materials from the rocks, for the development of new forms of food from the sea, for the generation of electricity from atomic power stations and of heat directly from the sun's radiation. Even if human affairs could be so organised that man were able to carry out these increasingly complex tasks on a world scale, and distribute the products with reasonable fairness, industrial civilisation would be overwhelmed by the enormous growth of population that would follow the introduction of modern scientific knowledge into these areas, unless their inhabitants were to practice family limitation on a large scale.

These are the conclusions of the author of this encyclopædic book, which examines, in some parts with almost cosmic detachment, in others with desperate urgency, the factors which enable civilisations of different types to achieve stability and the hopes for our own industrial society. The author is Professor of Geochemistry at California Institute of Technology, though much of the research and study he put into the preparation of this book was undertaken when he was on the staff of the Institute for Nuclear Studies, University of Chicago.

Before man started consciously to change his environment, while he depended entirely upon hunting and wild vegetation, the earth could probably never have supported a population of more than 10 million. Urban culture was made possible by the growth of new agricultural techniques freeing man from mere subsistence existence on the land. As these techniques spread throughout the European continent, populations increased even faster than the available food supply. Greece and Rome became dependent on imported grain, as Britain did in the latter half of the Nineteenth Century. In any civilisation, stability can only be reached if supplies of food and other resources rise as fast as the increase in numbers of the population. In the past this has rarely been achieved, the ratio of food to population oscillating between plenty and scarcity. When populations tended to rise too fast, they were restricted by natural selection, by disease and in the last resort by starvation. To-day, this is still the condition of the overwhelming majority of mankind, but the transfer of modern medical and sanitary knowledge from the advanced nations to the others is causing their net reproduction rates to rise much faster than the pace of their own industrialisation. It is the tensions caused by this increase, particularly among the nations already in process of transition to industrialisation, whose populations cast envious eyes on the wealth of the fully-industrialised nations, which are the most likely cause of war to-day.

Professor Brown examines the question of the possibility of a smooth and peaceful transition to industrial society of the under-developed areas. His conclusions are grim. He points out that the industrial nations of the West built their machine societies and their growing populations on the basis of increased food production and easily available minerals and fossil fuels. Britain's industrialisation was at first built on cheap coal and, later, on cheap food from North America. America acquired the capital to build her gigantic machine society by selling her easily grown food. The prophecies of Dr. Malthus were, therefore, proved false; a process which was assisted by the growth of the practice of birth control and by the expansion of populations into new areas.

This traditional process of industrialisation can never be repeated. To-day, in the agrarian societies, a significant increase in food production can only be achieved by mechanisation, which, in turn, requires a prior degree of industrialisation. Their people are, therefore, in a vicious circle. India has insufficient energy resources for a prolonged period of high production. She may, therefore, have to utilise atomic or solar energy long before the United States is forced to take equivalent steps. She will obviously be unable to do so without considerable help, both financial and technical, from outside.

For similar reasons Professor Brown believes that we are approaching the time when civilisation could not be rebuilt after a major war in which a large part of the industrial capital were destroyed. As our dependence shifts to such resources as low-grade ores, rock, seawater and the sun, the conversion of energy into work and of raw materials into manufactured products will require ever more intricate technical activity which would be impossible to start up without the substantial industrial foundation which we already have.

Assuming that war is avoided, is there any way out of these dilemmas? Certainly not, Professor Brown believes, without an unlikely degree of worldwide co-operation between nations, leading almost to federation, and a massive investment in the under-developed areas by the industrial nations on a basis far beyond the possibilities of private investment. To bring these areas within fifty years up to the level of industrialisation of pre-war Japan and to increase agricultural production, so that all their people received adequate nutrition, would require investments averaging about 5 billion dollars annually for the period.

But this would not be enough. If population growth is not to run ahead of the increases in production, the rate of reproduction would have to be controlled, and here Professor Brown puts forward some extraordinary proposals for endowing a world authority with jurisdiction over population problems. These proposals are all the more startling when considered in the light of the political developments that he thinks inevitable if mankind is to be able to undertake the appallingly difficult tasks he envisages for it. The increase of population densities, the growing specialisation and elaborateness of the organisations needed to produce food, extract raw materials and fabricate and distribute the finished products, will combine to produce more highly centralised government and increased regimentation leading to totalitarianism.

The deeply pessimistic outlook of this important book is supported by a mass of detailed facts and figures on population growths and the availability of resources. Where the author sometimes seems to get them rather out of focus is in relation to the time scale. In the immediate future, in some of the agrarian countries, particularly in the Middle East, oil is going to play the part that grain did in North America. Some of the most urgent problems are surely capable of solution, given reasonable goodwill, while some of the apparently most desperate problems will arise so far in the future that it may not be wishful thinking to consider whether the very facts themselves may not prove to be wrong.

Catalogue of the Scott Collection of Books, Manuscripts, Prints and Drawings. Compiled by Betty M. Cooper, A.L.A. *The Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.*1. (42*s.* net; 30*s.* to members of the Institution).

John Scott (1830-1903) was the fourth of that name to be associated with his family's shipbuilding business at Greenock, now that of Scott's Shipbuilding and Engineering Company, Limited, which was founded by the first John Scott in 1711. He was one of the earliest members of the Institution of Naval Architects and at the time of his death was a Vice-President of the Institution. His interests were unusually wide and one of them was the formation of a library of some 12,000 volumes, reputed to be one of the finest private collections in Scotland. At his death the greater part of it was sold, but the section devoted to shipbuilding and shipping was retained by his trustees and eventually was bought from them by his son, the late Mr. Robert Lyons Scott (1871-1939), and was presented by him in 1930 to the Institution, of which he was an Honorary Vice-President. It had been on loan to the Institution for some years, but was then placed in a separate room, known as the Scott Library.

The annotated catalogue of the Scott Library, on which Miss B. M. Cooper has been working for some two years, divides the 831 items into seven sections, preceded by a memoir of John Scott and a general description of the library, and followed by a bibliography, an author and title index, and a subject index. The first five of the seven catalogue sections deal with the printed books, separate sections being devoted to those of the Sixteenth, Seventeenth and Eighteenth Centuries, respectively, and the first and second halves of the Nineteenth Century. These together cover 797 of the 831 items. The sixth of the seven sections catalogues the manuscripts, and the seventh the prints and drawings. There is a portrait of Mr. John Scott as frontispiece, and 19 full-page reproductions of title-pages of the rarer books, sections of ships, etc., are distributed through the text. One of these, from a Dutch work by Cornelis van Yk, published in 1697, shows a vessel in process of being launched bow first and, except that it is to the opposite hand, resembles with remarkable fidelity a woodcut by W. H. Toms (c. 1700-50) which was reproduced in Vol. XII of *The Mariner's Mirror* (1926). There are differences, however, in the number and disposition of the men who are grouped round the vessel; but in a French print of 1712 (which may or may not be represented in the Scott Collection—the catalogue does not list prints in detail) in which the vessel duplicates precisely that of Toms, the attendant shipwrights are a combination of those in the Toms and van Yk illustrations. There can be no doubt that the three have a common origin, presumably van Yk.

Of the many notable items in this outstanding collection mention may be made of the *Instrucion Nauthica* of Diego Garcia de Palacio—the earliest known work on naval architecture, published in 1587 in Mexico City, which seems strange; the earliest of the eleven known copies of Sir Henry Manwayring's *Seaman's Dictionary* (c. 1620-23); the first (1664) edition of Edmund Bushnell's *Compleat Ship-wright*, which was the first English work on naval architecture; and the first (1671) edition of the famous work by Nicolaes Witsen, sometime Burgomaster of Amsterdam. The Collection is not solely concerned with shipbuilding, however; of more directly engineering interest are examples of Agricola's *De Re Metallica* (1561), Ramelli's *Diverse et Artificiose Machine* (1588), the English edition (1659) of De Caus' *New and Rare Inventions of Water-works*, Thomas Savery's *The Miner's Friend, or an Engine to raise Water by Fire* (1702), and a whole range of the volumes of Jacob Leupold's *Theatrum Machinarum* (1724-27). There is also an interesting collection of miscellaneous papers, mostly of the period 1790-1800, relating to canals and inland

navigation; Acts of Parliament dealing with dock and harbour works; and numerous nautical dictionaries, phrase-books, etc. The collections of manuscripts, and of prints and drawings, are much more extensive than the reference numbers indicate, as many of the items consist of portfolios; Nos. 822 and 823, for instance, contain together 269 engravings, issued in 1817, by Jean Jerome Baugean. It will be seen, therefore, that the Scott Library contains a remarkably comprehensive collection, which deserves to be better known by the members of the Institution which now has the good fortune to possess it. The catalogue is worthy of the Collection and is likely to be regarded in future not merely as a guide, but a source-book for those who seek to probe into the origin and development of naval architecture and its associated maritime sciences.

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TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Axial-Flow Fans. STURTEVANT ENGINEERING CO., LTD., Cannon-street, London, E.C.4. Comparison of axial-flow fan with centrifugal-type fan, characteristics, dimensions and speed. Applications of axial-flow fan, sizes of fans and details of different layouts. Advantages of blade pitch adjustment. Construction: rotors, guide vanes, casings, fairings, hubs, pre-swirl damper control, protection and motors. Illustrated booklet with diagrams and graphs.

Gearing. JOHN HOLROYD & CO., LTD., Milnrow, Lancs. Articles on gearing by Dr. H. Walker. Types of worm gears, materials used and trends in uses of worm gearing, causes of wear and failure; comparison between spur and helical gears, preparation of blanks for gear production, British Standard Specifications for gearing. Booklet containing reprints of articles published in *Holroyd News Letters*.

Water-Treatment Plant. WALLACE AND TIERNAN, LTD., Power-road, London, W.4. Automatic chlorination of water supplies, sewage, etc.; complete control of treatment is obtained by coupling the control to the chlorine-residual recorder. Illustrated leaflet describing company's model ASV(M) A259.

Turbo-charged Marine Diesel Engines. BURMEISTER AND WAIN, Copenhagen. Two-stroke cycle single-acting crosshead engines with exhaust turbo-charger for marine propulsion. Bore 500 mm.; stroke 1,100 mm.; gross i.h.p. from 10 cylinders, 6,450 h.p. at 170 r.p.m. Illustrated booklet describing the engines and some recent installations.

High-Power Electrical Testing Plant. OERLIKON ENGINEERING CO., Zürich, Switzerland. Fully illustrated descriptions in English of a new 1,500-MVA high-power testing plant for circuit-breakers. Details published in ENGINEERING, page 126, *ante*.

Hack Saw Blades. JAMES NEILL & CO., LTD., Napier-street, Sheffield. Hand blades, light power blades, heavy power blades; selection of tooth sizes, correct method of use, problems and their causes; tables of standard sizes. Booklet with drawings and diagrams.

Moving-Coil Voltage Regulators. FERRANTI LTD., Hollinwood, Lancashire. Motor-driven moving-coil voltage regulators for distribution and industrial circuits. Booklet gives particulars of operating characteristics and types available.

Manual and Handbook Production. THE MANDBOOK PRESS, Norfolk-street, London, W.C.2. Design, compilation and production of user handbooks and technical service manuals for industry and for the Services. Leaflet.

Wall Charts. ADAPTA-CHARTS, LTD., 93/4 Chancery-lane, London, W.C.2. Perforated panels with interchangeable plastic symbols, flags, pegs, ring-markers, title frames, letters, numbers, etc. Illustrated leaflet.

Oil Seals. PIONEER OILSEALING AND MOULDING CO., LTD., Colne, Lancashire. Installation and application of oil seals, showing tools for mounting seals; fully dimensioned list of standard seals. Comprehensively illustrated book.

Plastic Covering Material. LACRINOID PRODUCTS, LTD., Gidea Park, Essex. "Vietum" plastic covering for rods, tubes and bars, supplied in several colours. Illustrated booklet showing uses, properties and methods of application.

BOOKS RECEIVED

Some of the books noticed in the Books Received column are selected for extended review in later issues of ENGINEERING.

Metallurgy of the Non-Ferrous Metals. By W. H. DENNIS. *Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2.* (70*s*.)

This book covers the metals roughly in order of their industrial production, giving the source, the operations concerned in the extraction from the mineral, and the refining of the crude metal. In most cases, obsolete methods have been omitted, but historical facts have been included where they illustrate the background of modern developments.

Problems of Business Management. American Opinions—European Opinions. Technical Assistance Mission No. 129. *Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris* (16*e*). (280 francs); and *H.M. Stationery Office, Kingsway, London, W.C.2.* (5*s*. 6*d*.)

This is an analysis of the comments of European and American delegates to a conference on questions of industrial management, held in Paris in April, 1953. The more important points on which the conference concentrated were top management attitudes, subordinate management training, market research, and human relations. A list of recommendations arising from the discussions are given at the end of the report.

Strength of Materials. By JOSEPH MARIN and JOHN A. SAUER. Second edition. *The Macmillan Company, 60 Fifth-avenue, New York 11, N.Y., U.S.A.* (5 dols.); and *The Macmillan Company, New York, 10 South Audley-street, London, W.1.* (35*s*.)

The second edition includes two new chapters concerned with creep and temperature properties of materials, and experimental methods of stress analysis. There are also a number of additional sections including those on stress concentration, beam columns and vibrations of beams. The problems have been transferred from the ends of chapters to positions succeeding the relevant chapters, and problems of design have been directly incorporated with those on stress analysis.

Choosing Electric Cables. By C. C. BARNES. "Mechanical World" Monograph 67. *Emmott and Company, Limited, 31 King-street West, Manchester.* (3*s*. 6*d*.)

This monograph provides a comparative analysis of cable structures in relation to installation conditions. Impregnated-paper insulated power cables, the special designs of oil-filled and gas-pressure cables, and the merits of varnished-cambric insulated cables are discussed. Information is given on the wiring of buildings by means of vulcanised-rubber insulated cables, and the advantages and limitations of modern thermoplastic insulated cables and synthetic-rubber insulated cables are compared.

Technical Reports of the British Electrical and Allied Industries Research Association. *Offices of the Association, Thorncroft Manor, Dorking-road, Leatherhead, Surrey.*

Note on the Nature of Gases Liberated during Arcing in Oil Circuit-Breakers. By C. E. R. BRUCE. No. G/T260. (6*s*.) This report gives in tabular form E.R.A. and other data on the composition of gases evolved by arcing in insulating oils. The E.R.A. data already given in Ref. G/XT35 are amplified and, in particular, the few results obtained with a naphthene-base oil are quoted.

Series Breaks in Circuit-Breakers: A Technique for the Measurement of Voltage Distribution. By F. O. MASON. No. G/T281. (10*s*. 6*d*.) This report is concerned with measuring technique and shows how, in investigating the manner in which restriking voltage divides between series breaks in a circuit-breaker, errors can be introduced in recording and in the setting up of the measuring apparatus, which may give rise to unreliable results. A simple comparison method is then described.

Oriented Polystyrene Film Capacitors: A Major Cause of Premature Breakdown. By H. F. CHURCH. No. L/T289. (7*s*. 6*d*.) Difficulties have been encountered in the industrial production of polystyrene film capacitors owing to the very high rejection rate on heat treatment of the units. It has been shown that the main cause of failure is the inadvertent introduction by the machine operators of occasional particles of greasy material, the grease having a plasticising action on the film during the heat treatment and causing holes to be formed in the neighbourhood of the particles by local relaxation of the oriented polystyrene film. Precautions in manufacture to avoid this trouble are suggested.

The Dielectric Properties of Silicone Liquids and Greases—III. By E. RUSHTON and J. V. L. PARRY. No. L/T296. (7*s*. 6*d*.) The dielectric properties of silicone liquids of viscosity from 12,500 to 200,000 centistokes have been studied over a frequency range of 60 c/s to 24,000 Mc/s. The results confirm the findings of previous reports, that from the point of view of dielectric properties, the silicone liquids fall into two classes, the first class comprising the liquids of low viscosity, and the second class the high viscosity liquids (from 20 centistokes upwards).

An Investigation on Aluminium Electrolytic Capacitors and the Development of a New Type of Aluminium Oxide Capacitor. By G. C. ROBINSON. No. L/T305. (15*s*.) The object of the investigation described in this report was to determine whether the working temperature range of aluminium oxide electrolytic capacitors could be extended. Part I covers investigation of different kinds of industrial electrolytic capacitors, determination of their temperature characteristics, and the study of their performance under stress at elevated temperature. Part II is a fundamental study of the anodic forming process and of the properties of the oxide layer.

Deposits on Overhead Line Insulators Exposed to Wind-Borne Salt Spray. By G. MOLE. No. O/T12. (12*s*.) A satisfactory technique has been established and is in operation by B.E.A. for assessing the relative merits of various types of overhead line insulators in relation to their performance under conditions of industrial pollution. No corresponding technique is available for assessing the performance of insulators under conditions of salt pollution. An account is given of tests involving exposure of insulators to salt pollution from sea air, in order to assess the conditions which have to be reproduced when a laboratory test is devised.

The Friction Coefficient for Circular Pipes at Turbulent Flow. By J. R. FINNIECOME. *Emmott and Company, Limited, 31 King-street West, Manchester.* (10*s*.)

The main purpose of this book is to examine published data, to show the relationship of the various formulæ and test results, to review and emphasise particularly the essential factors influencing the friction coefficient in circular straight pipes, and to correlate and present in the form of charts, information relating to the pressure drop in smooth and rough pipes.

The Villiers Engine for Industrial, Agricultural and Horticultural Use. A Practical Guide to Maintenance and Overhaul. By B. E. BROWNING. *C. Arthur Pearson, Limited, Tower House, Southampton-street, Strand, London, W.C.2.* (6*s*.)

This book gives full servicing and maintenance instructions for Villiers two-stroke and four-stroke industrial engines. The section dealing with four-stroke engines covers all models made since the introduction of this type. The section dealing with the two-stroke engine, while concerned with post-war engines, will be of use to owners of pre-war engines of this type. Fault-finding charts are also given for both two- and four-stroke engines.

Honduras. Overseas Economic Survey. By J. P. COGHILL. Published for the Board of Trade, Commercial Relations and Exports Department, by *H.M. Stationery Office, Kingsway, London, W.C.2.* (1*s*. 3*d*.)

This is a further issue in the series of Overseas Economic Surveys giving details of economic and commercial conditions in Honduras. The survey covers finance, production and industry, trade, transport and communications, exports and imports.

Surveying and Levelling for Students. By DR. BERNARD H. KNIGHT. *Contractor's Record and Municipal Engineering, Lennox House, Norfolk-street, London, W.C.2.* (18*s*.)

This book has been written as a textbook for surveyors, civil, municipal and structural engineers, architects, builders and contractors, but more particularly for students preparing for the examinations of the Royal Institution of Chartered Surveyors, the Institution of Structural Engineers, or the Institute of Quantity Surveyors. It also serves as an introduction to the subject for those sitting the professional examinations of the Institution of Civil Engineers and the Institution of Municipal Engineers. Its primary aim is to combine the field-work necessary in surveying and levelling with the office work required to produce accurately, speedily and economically the plan or section, and to show the student how these two processes are bound up with each other.

ELECTRICITY SUPPLY IN EUROPE

FACTORS AFFECTING EXPANSION AND REPLACEMENT OF PLANT

Conditions that have affected the growth of electricity supply in Western Europe during the past 50 years, and that are likely to affect it during the next four years, are discussed in a report prepared by a committee of experts, including representatives from the United Kingdom, Germany, France and the United States, under the sponsorship of the Organisation for European Economic Co-operation (O.E.E.C.).* This is the first time an attempt has been made to obtain data on electricity supply from several countries—in this case 18, including the United States—and to draw conclusions therefrom.

The rate of increase in the demand for electricity, for O.E.E.C. countries taken as a whole, has been 6 to 7 per cent. a year over a long period and " is expected to continue at this level for some decades ahead." This means that capacity will have to be doubled every 10 to 12 years. The average annual (geometric) rate of increase in electrical power production varies widely between countries, from 3·2 per cent. in the case of Greece during the period 1920-51 to 13·0 per cent. in the case of Turkey. The effect of the war on the rate of electrification of certain countries has been considerable. The average annual increase in Germany, for example, was 10·4 per cent. in the period 1920-38, −6·4 per cent. in 1938-45 and 18·7 per cent. in 1945-51. The corresponding figures for this country were 9·9, 6·2 and 8·3 and for the United States 10·5, 13·6 and 11·1. The highest rates of increase in electrical power production since the war have been in the Netherlands (30·4 per cent. per annum), in Germany (18·7 per cent.) and in Italy (15·0 per cent.), each of which suffered losses of capacity during the war. Only in the case of the United States was the rate of increase during the war higher than either before or since. It is interesting to note that the rate of increase in the United Kingdom since the war (8·37 per cent.) has been somewhat less than in the period 1920-38 (9·9 per cent.). This has been caused mainly from shortage of materials, labour and plant, and the rate is therefore more likely to rise than to fall.

RESTRICTION BY PRICE

The committee's conclusions on the trend of electricity prices are, broadly, that price is unlikely to restrict the demand for electrical power. In fact, they suggest that prices should be kept sufficiently high to prevent misuse of a commodity that in their view must remain scarce for a very long time. This is a very interesting viewpoint, for which there is no lack of evidence. They write: " Should the electricity supply industry be unable for various reasons to meet an unrestricted demand, the consequences might be particularly serious at a time when everything points to a more intensive use of electrical power. . . ." Electrical power undertakings may find, however, that the downward trend in the real cost per kWh will cease during the next few years; " already it has become noticeably weaker." The following factors militate against further reductions in electricity prices and might, in fact, lead to an increase in real costs per kWh :

(1) Relatively little scope is left for improvements in the efficiency of thermal plant installed to meet future increases in demand, since the practical limits set by the laws of thermodynamics are being approached, apart from the possibilities of radical improvement inherent in new technical developments, such as may result from the use of nuclear energy.

(2) Hydro-electric stations have been built at most of the more suitable points and the harnessing of water at additional points is tending to become more costly. This applies to the United States as well as to most countries in Western Europe.

(3) Only small further benefits can be expected from the extension of the interconnection systems that have been developed in Western Europe at both international and national points.

(4) The fairly widespread tendency to reduce working hours in the electricity consuming industries is tending to lower the load factor for plant supplying industrial users, unless there is a compensating increase in shift working, which seems less likely in Western Europe than in the United States.

(5) The campaign in most countries for an optimum use of coal in other industries may entail the use of less economical sources of energy for generating electricity.

(6) The fact that new thermal plant required to replace old units will require heavy expenditure, the capital charges on which " may not be wholly compensated by the higher efficiency obtainable from the newer plant." This suggests that the prices of modern generating and distribution plant have increased so much that depreciation allowances are inadequate to pay for new plant.

The Committee's conclusion—that the electricity prices are more likely to rise than to fall—was also the conclusion reached in the United States by the President's Materials Policy Commission.* In that country hydro-electricity supply has a lower average cost than thermal electricity but the few sites that are left " will entail higher average costs for the electricity produced." The major factor is, however, the likelihood of a rise in fuel costs: " the real cost of oil and particularly natural gas for thermal generation may rise considerably, thus forcing up thermal electrical costs." The reason given for this most important conclusion—reached after a very detailed examination of U.S. and Western European resources—is that available supplies of these fuels are likely to become scarce. The importance of this to the U.S. and to Western European nations is such that the development of additional sources of thermal energy—on which further industrial expansion and increased productivity must depend—must soon become the leading national endeavour.

ELECTRICITY COSTS IN MANUFACTURE

The report contains a wealth of information about the cost of electricity in relation to other industrial costs, and also as an item in family budgets. A survey carried out in the United States shows that apart from a few exceptions such as primary aluminium, blast furnaces, pig-iron and steel produced by electro-metallurgical processes, raw materials account, on an average, for 48·48 per cent. of total manufacturing costs, overheads and profits for 22·07 per cent., commissions and contracts expenses for 2·47 per cent., fuel for 1·91 per cent. and electrical power for only 0·59 per cent. A survey of industry in Belgium showed that power costs do not usually account for more than 2 per cent. of the market value of industrial production and manufactured goods taken as a whole. They vary between 0·5 per cent. and 10·0 per cent., the latter being a maximum applying to industries where electricity is practically the only form of energy used. The influence of electricity costs on all items produced with light electrical hand tools is extremely small; it is not very great even for small and medium horsepowers and becomes comparatively significant only when heavy torques are required over continuous periods, e.g., crushers, grinders, rolling mills, centrifugal equipment, pumps, compressors, etc. Expenditure on electricity in households averaged 1·2 per cent. of family budgets and did not exceed 1·6 per cent. in any of the families covered by the survey. Expenditure on farms, calculated on the basis of specific power consumption per production unit, rarely exceeded 1 to 1½ per cent. of the total value of the farm's output, though this did not take into account the capital cost of electrical equipment, which was said to be " the main obstacle to rural electrification."

The low incidence of electrical power costs, and the fact that electricity will remain scarce in the foreseeable future, are sound reasons for not keeping rates at an artificially low level, although the Report argues that " if rates are too high electric power meets with competition from other forms of energy and its development is held back." Against this, it should be realised that electric power has a good many attractions both in factories and in homes—not least its cleanliness, but also the compactness of electrical machinery and the flexibility of electricity as a source of heat.

PROBLEM OF CAPITAL

The major problem facing the industry in practically all countries surveyed is to secure adequate supplies of capital; partly this is due to the political influences. The O.E.E.C. committee deplore this and conclude that a necessary condition of growth is that " the electricity supply industry should be allowed sufficient freedom to be run on sound economic principles so that the raising of the capital required may be facilitated." Once again the United States is no exception to the general rule. Between 1925 and 1950, the average price paid for electric power by industrial and commercial customers (adjusted for changes in the purchasing power of the dollar), dropped 58 per cent. and by residential users 70 per cent. Yet the electrical supply industry in the United States can turn over its capital only once in four years or more whereas the motor industry can do so every six months, and manufacturing industry as a whole every eight months. Moreover, the capital employed by electricity undertakings is very much higher per worker than in any other industry. In the United States in 1948 it amounted to over five times that invested per worker employed in manufacturing industry as a whole and nearly 1½ times that invested per worker employed in the chemical industry. It follows therefore that the cost of electrical power production plant and transmission equipment is a vital factor in electrical power costs.

In 1952 the cost per kW of production capacity was lowest in Sweden, ranging from 97 dols. to 116 dols.; other low cost countries were the United States (119 dols.), Germany (131 dols.), and the Netherlands (131 dols.). The average cost per kW in the United Kingdom (168 dols. in 1951) was the highest figure shown. Distribution equipment costs, on the other hand, were relatively low in this country (14·8 dols. per km. of line 200 kV normal in flat country), compared with 22½ dols. in the United States, 16 dols. in Italy and 26 dols. in the Netherlands. It would be interesting to have a manufacturer's view on such differences.

The Committee's view of the future is, on the whole, optimistic, with a caveat inserted concerning the high cost of plant and inadequate supplies of capital. Eastern European capacity (global load at bus-bars of power stations) is expected to rise from 68·1 million kW in 1954 to 87·7 million kW in 1958, an increase of 29 per cent. The projected increase in respect of this country is 26 per cent.; in respect of Germany, 24 per cent.; France, 31 per cent., and Italy, 40 per cent. The capacity in the United States, 92·2 million kW in 1954, is expected to increase to 106·6 million kW by 1956, thereby remaining about 35 per cent. above that of Western Europe as a whole.

* *The Price of Electricity and its Relation to Investment in the Electricity Supply Industry*, Organisation for European Economic Co-operation, Paris, October 25, 1954.

* *The President's Materials Policy Commission—Resources for Freedom.* Volume III—Outlook for Energy Sources, Washington, June, 1952.

THE TORSION CENTRE OF GIRDERS

APPLICATION OF SHELL ANALYSIS TO STRUCTURAL SECTIONS

By J. S. Terrington, B.SC.(ENG.), A.M.I.C.E., A.C.G.I.*

Since the earliest papers on the elastic stability of beams, prepared independently by Prandtl[1] and Michell[2] in 1899, much has been written on the theory relating to beams which are subjected to bending and torsion. Cases which have been considered have included an elementary thin strip, shown in Fig. 1*b*, and a bi-symmetrical I-section with vertical loads, in Fig. 1*c*[3, 4]; box and I-sections under vertical and lateral loads through the shear centre, Fig. 1*d*[5]; pure torsion of an I-section, Fig. 1*f*[6]; an I-section under vertical eccentric point and uniform loads, Figs. 1*g* and *h*[6]; and a mono-symmetrical I-section under vertical and lateral eccentric point loads, Fig. 1*j*[7]. This selection is typical of the range of sections and loadings dealt with but does not include the work of, for example, Stüssi, Meissner, Dohrenwend, Federhofer, Young, Prescot, Flint and many others of those who have contributed papers on various aspects of the theory. It will be seen that the types of section have been relatively simple but that they have progressed, if slowly, in comparative complexity.

STABILITY EQUATIONS

The general equations[3, 8] for elastic stability—the characteristic dimensions are shown in Fig. 1*a*—are three in number expressing: (1) bending about the *xx*-axis, (2) bending about the *yy*-axis, and (3) torsion about the *zz*-axis or centre of torsion.

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These three equations are of the form:

$$M_x' = -EI_x\frac{d^2v}{dz^2} = -M_x + M_y\phi + M_z\frac{du}{dz}, \quad . \quad . \quad (1)$$

$$M_y' = -EI_y\frac{d^2u}{dz^2} = +M_x\phi + M_y - M_z\frac{dv}{dz}, \quad . \quad . \quad (2)$$

$$M_z' = GJ\frac{d\phi}{dz} - C_w\frac{d\phi^3}{dz^3} = -M_x\frac{du}{dz} + M_y\frac{dv}{dz} + M_z, \quad (3)$$

where EI_x, EI_y are the principal major and minor flexural rigidities, GJ the torsional rigidity and C_w the warping coefficient.

Subject to a suitable allowance for the inclination (if any) of the principal axes, the estimation of the bending moments about the *xx*- and *yy*-axes are mostly straight forward but, in principle, the correct assessment of the torsional moment, M_z, presents some difficulty. The difficulty arises because the point about which the section will rotate—and that is the point from which the eccentricity of the horizontal and vertical loads must be measured to calculate the torsional moment—is not necessarily the centre of area of the section. In the elementary sections considered by the earlier investigators, this question of the true centre of rotation did not arise because the centre of rotation was mostly at the centre of area of the section. With wholly asymmetrical sections, however, the exact location of the centre of rotation becomes a difficult problem and, in this connection, it is important to have a clear definition of the centre of rotation.

When an asymmetrical beam or girder bends under transverse load, the shear stresses produced by the shear force give a resultant which does not usually pass through the centre of area of the cross-section; and when the girder bends about one or more axes in succession, there is one point in the cross-section through which the resultant of the shearing stresses always passes; this is termed "the shear centre." If the resultant of the external shear force does not pass through this "shear centre," it is found that the girder twists so that the shear centre is also the "centre of rotation," that is, the centre about which the section naturally twists.

In structural steelwork design, members, such as, for example, I-beams, are mostly symmetrical in cross-section and they are usually subjected to symmetrical loads. This type of loading produces pure bending and transverse shear stresses and avoids any tendency of the section to twist. Cases do occur, however, in which the load is eccentric, so causing the beam to twist as well as to bend. Beams carrying spandrel walls are often subjected to this type of loading and so are crane-gantry girders carrying overhead travelling cranes, where twisting is due to the eccentricity of the vertical wheel load, to lateral surge from the cranes as well as to lack of symmetry in the beam cross-section. Problems involving torsion on simple sections have been tackled by investigators[9] but it is believed that no text-books have given a quick and easy method of solution; for this reason, the solutions for cases in practice have been largely guessed. Where the section has been wholly asymmetrical, empirical approximations have been resorted to.

Since the earliest papers on torsion,[3, 10, 11] much consideration has been given to the analysis of thin-walled shells under bending and torsion, particularly in relation to aircraft frames[12]. From these papers there has emerged very clearly the idea that every section has a natural centre of rotation. Moreover, in spite of all that has been written, it is only comparatively recently[13]

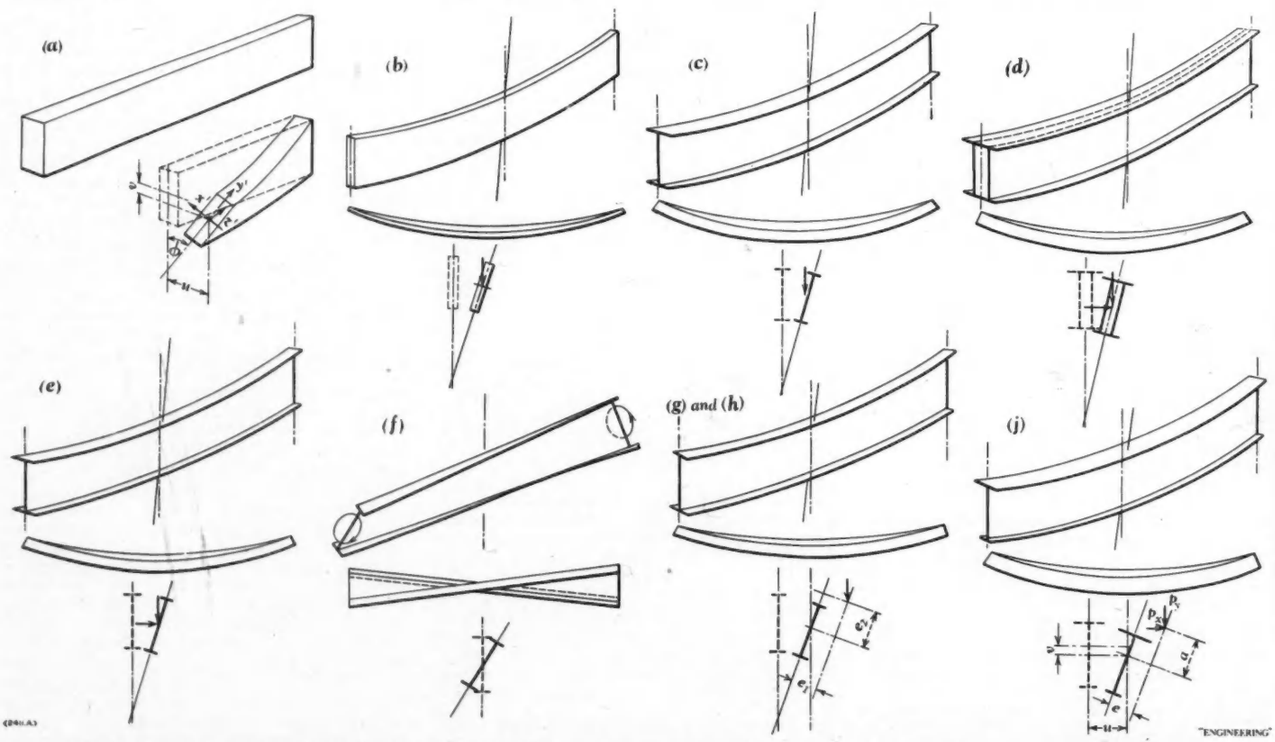

Fig. 1 Beams of different sections under various types of torsion loading that have been treated in earlier papers (see bibliography).

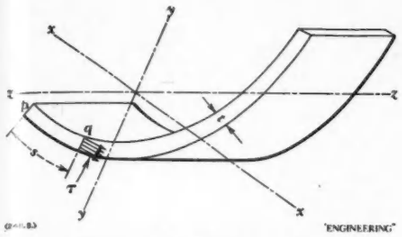

Fig. 2 Shear stress in thin-walled open sections. General equations for this type of shell section can be extended to cover conventional structural sections.

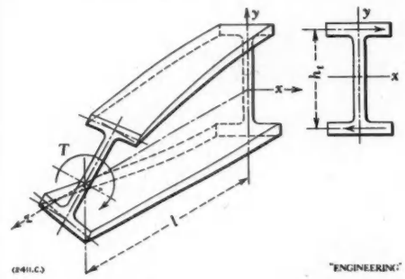

Fig. 3 Part length of a beam, vertically hinged at the support to allow warp but to resist rotation, subjected to torque at the mid-span section.

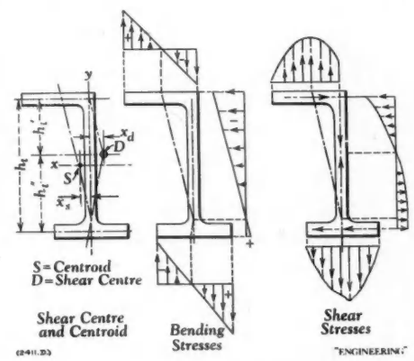

Fig. 4 Stress distribution and location of shear centre and centroid of an elementary asymmetrical open-sided section.

that the general equations for shear stress across a section have been postulated, and it is these equations which are required to locate the centre of rotation. As far as is known all earlier writers have used an approximation of the general equations which does not give correct results. Furthermore, and this is not by any means appreciated, by adopting the equations deduced by shell analysis, it becomes possible to arrive at the centre of rotation of asymmetrical open-sided structural sections, and then to make a reasonably accurate estimate of the torsional stresses. In view of its importance, it is of interest to discuss the position of the shear centre or centre of rotation in girder sections, and to re-examine an example based on an original paper.[14]

CALCULATIONS

The method which is most generally applicable to any section is to calculate the position of the resultant of the shear stresses across a section when the section is considered to be bent, in succession, about two directions at right angles; the intersection of these two resultants gives the position of the shear centre. The "shear intensity" or "shear flow" at any point in the cross-section is the shearing force per unit length, as shown in Fig. 2.

When loaded in the yz-plane,

$$\tau t = -\frac{V_y}{I_x I_y - I_{xy}^2}\left(I_y \int_0^s y\,t\,ds - I_{xy}\int_0^s x\,t\,ds\right), \quad . \quad . \quad (4)$$

and when loaded in the xz-plane,

$$\tau t = +\frac{V_x}{I_x I_y - I_{xy}^2}\left(I_{xy} \int_0^s y\,t\,ds - I_x\int_0^s x\,t\,ds\right), \quad . \quad . \quad (5)$$

where

τt = the shear intensity per unit length of section (measured in the direction of s),
V_x = the shear force when applied along the x-axis,
V_y = the shear force when applied along the y-axis,
I_x = the moment of inertia of the complete section about the xx-axis,
I_y = the moment of inertia of the complete section about the yy-axis,
I_{xy} = the product of inertia of the complete section,
x = the abscissa of any element of section ($t\,ds$),
y = the ordinate of any element of section ($t\,ds$),
t = thickness of section,
s = length of cross-section from the outer end ("p" in Fig. 2) to the point ("q" in Fig. 2) considered,

and ds = any element of the length "s."

These expressions give the distribution of the shear intensity and they have to be integrated over the section in order to obtain the total shearing force. Evaluation of the position and magnitude of these two shear forces at right angles and locating their intersection gives the position of the shear centre.

These equations will be more generally recognised when the x- and y-axes are the principal axes; in this case, $I_{xy} = 0$ and their form reduces to the well-known simple equations for the calculation of shear stress in symmetrical beams and girders, viz.:

$$\tau t = -\frac{V_y}{I_x}\int_0^s y\,t\,ds,$$

$$\tau t = +\frac{V_x}{I_y}\int_0^s x\,t\,ds.$$

The position of the shear centre of an asymmetrical open section has also been calculated from first principles[11] when the girder is twisted under restraint, as for example, when subjected to a tortional moment at mid-span and simultaneously restrained from twisting at the ends. This example is depicted in Fig. 3.

The complete deformation of the section is complex and is the result of a number of effects which can be evaluated separately as follow:

(1) The bending of the upper portion of the beam to the right and the lower portion of the beam to the left, both about the y-axis of the flange as the neutral axis.

(2) A varying tension and compression of the longitudinal fibres over both parts of the cross-section, on to which is superimposed the stresses from the differential bending referred to above.

(3) The bending of the web, due to the angle of twist.

(4) The bending of the whole beam about the x-axis.

It is not necessarily practicable to carry out such an analysis for any particular section, but it is possible to use the three final equations giving the position of the shear centre, for open-sided sections such as are sometimes used for crane-gantry girders. These equations, as they relate to the section shown in Fig. 4, are:

$$x_d = h_t \times \left[\frac{I_y' I_{xy}'' - I_y'' I_{xy}' - x_s(I_{xy}'' F' x_s' - I_{xy}' F'' x_s'')}{I_x I_y - I_{xy}^2 - I_x x_s^2 F}\right] \quad . \quad . \quad (6)$$

$$h_t' = h_t\left[\frac{I_y'' I_x - I_{xy}'' I_{xy} - I_x x_s F'' x_s''}{I_x I_y - I_{xy}^2 - I_x x_s^2 F}\right], \quad . \quad . \quad (7)$$

$$h_t'' = h_t\left[\frac{I_y' I_x - I_{xy}' I_{xy} - I_x x_s F' x_s'}{I_x I_y - I_{xy}^2 - I_x x_s^2 F}\right], \quad . \quad . \quad (8)$$

where

I_x = the moment of inertia of the complete section about the xx-axis,
I_y = the moment of inertia of the complete section about the yy-axis,
I_{xy} = the product of inertia of the complete section,
F = the cross-sectional area of the complete section,
x_s = the distance of the centroid of the complete section from the yy-axis,
x_d = the distance of the shear centre from the yy-axis,
h_t = the distance apart, centre to centre, of the flanges,
h_t' = the distance of the shear centre from the centre-line of the upper flange, and
h_t'' = the distance of the shear centre from the centre-line of the lower flange.

In these expressions, the quantities without dashes relate to the complete section; those quantities with single dashes refer to the portion

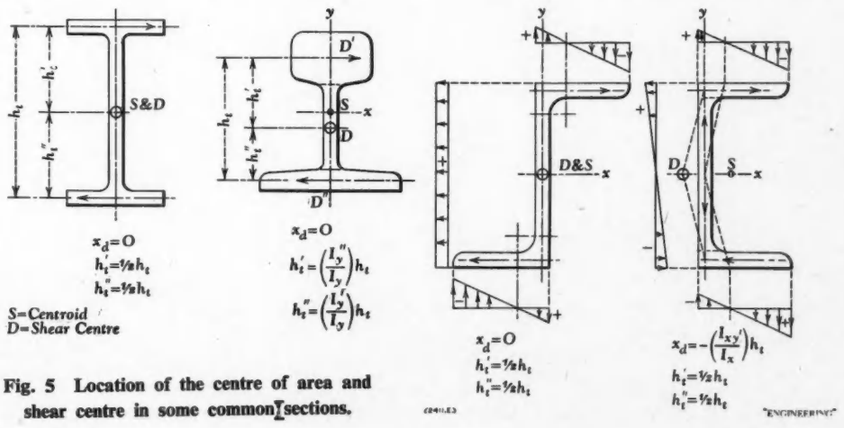

Fig. 5 Location of the centre of area and shear centre in some common sections.

TABLE I.—CALCULATION OF THE SHEAR CENTRE FOR THE CRANE-GIRDER GANTRY SHOWN IN FIG. 7.

$I_x = 51{,}620$ in.^{4}. $I_y = 33{,}690$ in.^{4} $I_{xy} = 8{,}030$ in.^{4}

$I_x I_y - I_{xy}^2 = 1{,}670 \times 10^6$ $\quad \frac{I_x}{I_x I_y - I_{xy}^2} = 30{\cdot}9 \times 10^{-6}$

$\frac{I_y}{I_x I_y - I_{xy}^2} = 20{\cdot}2 \times 10^{-6}$ $\quad \frac{I_{xy}}{I_x I_y - I_{xy}^2} = 4{\cdot}8 \times 10^{-6}$

Point (1)	Item (2)	Area (sq. in.) (3)	x (in.) (4)	y (in.) (5)	τt* (6)	τt† (7)
1	5 × 3 × ⅜	2·86	+49·8	−34·52	$+V_y$ 2,676 × 10^{-6}	$-V_x$ 4,873 × 10^{-6}
2	5 × 3 × ⅜	2·86	+49·8	−34·52	$+V_y$ 2,676 × 10^{-6}	$-V_x$ 4,873 × 10^{-6}
3	5 × 3 × ⅜ 8 × 4 × ⅜	2·86 4·36	+49·8 +47·7	−34·52 +19·33	$+V_y$ 1,974 × 10^{-6}	$-V_x$ 10,920 × 10^{-6}
4	5 × 3 × ⅜ 8 × 4 × ⅜ 43¼ × ⅜ pl (part of)	 42·29 × ⅜	+49·8 +47·7 +21·15	−34·52 +19·33 +18·73	$-V_y$ 2,430 × 10^{-6}	$-V_x$ 19,840 × 10^{-6}
5	14 × 1¼	17·5	− 9·33	−35·58	$+V_y$ 11,815 × 10^{-6}	$+V_x$ 2,060 × 10^{-6}
6	14 × 1¼ 52⅜ × ½ pl	17·5 26·5	− 9·33 − 9·33	−35·58 − 8·64	$+V_y$ 15,230 × 10^{-6}	$+V_x$ 8,570 × 10^{-6}
7	14 × 1¼ 52⅜ × ½ pl 16 × 1¼ 100 lb./yd	17·5 26·5 20·0 9·8	− 9·33 − 9·33 − 9·33 − 9·33	−35·58 − 8·64 +19·30 +20·43	$+V_y$ 2,300 × 10^{-6}	$+V_x$ 19,875 × 10^{-6}
8	43¼ × ⅜ pl (part of) as point 7 above	1·0 + ⅜	− 0·5	+18·73	$+V_y$ 2,300 × 10^{-6}	$+V_x$ 19,875 × 10^{-6}
Shear forces, between points:— (1)—(2) (3)—(4) (5)—(6) (7)—(8)					$+V_y$ 133 × 10^{-3} $-V_y$ 10 × 10^{-3} $+V_y$ 742 × 10^{-3} $+V_y$ 21 × 10^{-3}	$+V_x$ 242·5 × 10^{-3} $+V_x$ 700 × 10^{-3} $+V_x$ 280 × 10^{-3} $+V_x$ 186 × 10^{-3}
Moment of Shear Forces about Centroid					$+V_y$ 2,132 × 10^{-3}	+ V_x 31,720 × 10^{-3}
Point of Action of Shear Forces.—					$= \frac{V_y}{+2{,}132} \times 10^{-3} \times \frac{V_y}{V_y}$ $= \frac{+2{,}132}{133 + 742} \times 10^{-3} \times \frac{V_y}{V_y}$	$= \frac{V_x}{+31{,}720} \times 10^{-3} \times \frac{V_x}{V_x}$ $= \frac{+31{,}720}{886} \times 10^{-3} \times \frac{V_x}{V_x}$
					= − 2·33 from centroid = 9·33—2·33 = 7·0 *in. from centre line of main girder*	= + 35·8 from centroid = 35·8—18·93 = 16·8 *in. from upper face of walkway*

* $\tau t = \frac{+V_y}{I_x I_y - I_{xy}^2}\left(I_{xy}\int_0^s x\,t\,ds - I_y\int_0^s y\,t\,ds\right)$: † $\tau t = \frac{-V_x}{I_x I_y - I_{xy}^2}\left(I_x\int_0^s x\,t\,ds - I_{xy}\int_0^s y\,t\,ds\right)$.

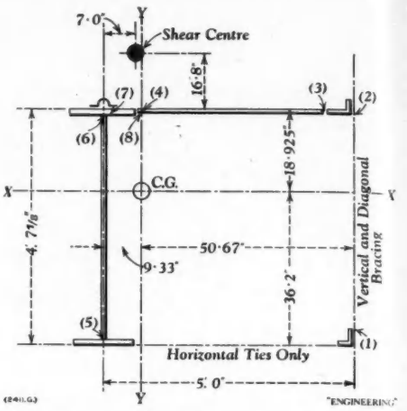

Fig. 7 Crane-gantry girder section; the location of the shear centre for this girder is determined as a worked example.

above the *xx*-axis; and those quantities with double dashes refer to the portions below the *xx*-axis.

For typical structural sections, these three expressions giving the co-ordinates of the position of the shear centre simplify to those given in Fig. 5 on the previous page.

APPROXIMATE POSITION OF THE SHEAR CENTRE

Most structural sections, such as the I-beam, are symmetrical about their two principal axes and in these sections the shear centre, as well as the neutral axis, is at the centre of area. One essential feature, however, of asymmetrical sections is that the shear centre does not occur at the centre of area. Moreover, it can even occur, as in the channel section, quite outside the outlines of the section.

To obtain a concise view of the problem as is possible, it is instructive to make a survey of the approximate position of the shear centre in sections which are regularly used in structural work; these are shown in Fig. 6, where the position of the shear centre is indicated. The I-beam in Fig. 6*a* is symmetrical about the

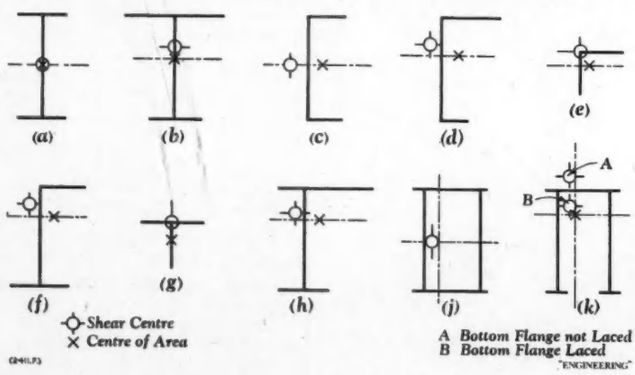

Fig. 6 Approximate location of the centre of area and shear centre in some compound sections.

xx- and *yy*-axes and the shear centre, as already mentioned, is at the centre of area. In Fig. 6*b* the increased width of the top flange causes the centre of area to rise but the shear centre has risen still higher. In the channel, Fig. 6*c*, the centre of area is inside the section, but the shear centre is on the *xx*-axis and outside the web. In Fig. 6*d* the increased width of top flange again causes the centre of area to rise within the section, but the shear centre is even higher and still outside the section. As one flange continues to increase and the other decrease, the shear centre virtually travels towards the corner of the larger flange until in the angle, Fig. 6*e*, in which the lower flange has disappeared, the shear centre is actually at the junction of the web and flange, that is, where the two portions intersect at right angles. The sections in Figs. 6*f* and 6*h* have the characteristics of the channel, and the T-section, Fig. 6*g*, resembles the angle in that the shear centre is at the junction of the two portions at right angles. In Fig. 6*j* a box girder is formed by two girders of different cross-section. If the top and bottom booms are of the same sectional area for each girder, the shear centre is on the *xx*-axis through the centre of area, but it will not necessarily be located in the same position as the centre of area. Where the upper flange is larger than the lower flange and includes a plated walkway, as in Fig. 6*k*, the centre of area is off centre and the shear centre may be inside or outside the section depending on the way in which the bracing is provided.

WORKED EXAMPLE

An example, the crane-gantry girder section shown in Fig. 7 and evaluated in Table I, will show the way in which the method of calculation can be applied; tabulation of the results as far as possible is, of course, the easiest and clearest way of dealing with the figures.

Considering the shear-flow method, and having calculated the values of I_x, I_y, I_{xy}, and

$$\frac{I_x}{I_x I_y - I_{xy}^2}, \quad \frac{I_y}{I_x I_y - I_{xy}^2} \quad \text{and} \quad \frac{I_{xy}}{I_x I_y - I_{xy}^2}$$

are evaluated. Each of the points where the section changes and where the shear flow is required are numbered correspondingly in column (1) of the table and in the figure. Against each point is stated the area of each part of the section between the point considered and the outer limit of the section where the shear stress is zero. For example, beyond point (3) there are two angles (5 in. by 3 in. by ⅜ in. and 8 in. by 4 in. by ⅜ in.) and their areas and the co-ordinates of their respective areas are set down in columns 3, 4 and 5. Using the

factors involving I_x, I_y and I_{xy} already calculated, the values of each of the expressions

$$\frac{+V_y}{I_x I_y - I_{xy}^2}\left(I_{xy}\int_0^s x\,t\,ds - I_y\int_0^s y\,t\,ds\right)$$

and

$$\frac{-V_x}{I_x I_y - I_{xy}^2}\left(I_x\int_0^s x\,t\,ds - I_{xy}\int_0^s y\,t\,ds\right)$$

are evaluated at the same time and entered in the last two columns, (6) and (7), respectively.

Having found the shear intensity or shear flow at each of the critical points in the section, the shear force between each pair of points is calculated as the average shear force over the part of the section multiplied by the distance between the sections. From the consideration of area moments, it is to be noted that the variation in the shear flow in a portion of the section at right angles to the direction of the shear is linear and, in line with the shear, the variation of shear flow is parabolic. The total moment of the shear forces about the centroid is obtained from the summation of the products of each of the separate shear forces and their respective lever-arms about the centroid and taking into account the directions of the shear forces. The distance of the line of action of V_y from the centroid is given by the total moment of the shear forces (a function of V_y) divided by V_y. The distance of the line of action of V_x from the centroid is obtained by a similar calculation, considering the shear V_x to act along the xx-axis.

It will be seen that the portions of the cross-section subjected to bending stresses are used in the calculation including, for example, the walkway. Those areas connected by diagonal bracing which can transmit shear have a uniformly constant shear stress (or shear flow) across them; and those areas connected only by spacing ties or struts and which cannot transmit shear must be regarded as being open.

The second method gives approximate results and involves substitution in the appropriate equations for x_d, h_i' and h_i''.

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BOUNDARY-LAYER CONTROL

USING THE AERO ENGINE TO INCREASE LIFT AND REDUCE DRAG

In the practical engineering and installation of boundary-layer control, and in undertaking flight research, "a good deal of leeway has to be made up in Great Britain," Dr.-Ing. G. V. Lachmann, director of research at Handley Page, Limited, stated in a lecture entitled "Boundary Layer Control," which he delivered to the Royal Aeronautical Society on Thursday, November 11.

Dealing firstly with the use of boundary-layer control for preventing flow separation and premature stall either by increasing the kinetic energy of the flow by "blowing" (the simplest method) or by sucking the boundary layer away, or by a combination of both methods, which is probably more efficient from the point of view of mass flow. Dr. Lachmann recalled that the first flight tests with boundary-layer suction were undertaken in 1936 in Germany on a Fieseler Storch aircraft, and German research continued until the end of the second World War, after which it was followed up in France, where the idea of bleeding air from jet engines to energise the air flow originated, and in America.

CONTROLLABILITY AT LOW SPEEDS

The most successful demonstration of a practical engineering solution using the blow-out method over the flaps was given this year in the United States on a Grumman Panther aircraft. Mr. John Attinello, of the Bureau of Standards, was responsible. The take-off speed was reduced by 20 knots and it was possible to take-off with a bomb load increased by 3,000 lb. Controllability at low speeds was greatly improved. The most obvious applications for circulation control were for deck-landing aircraft and for a new type of short-haul passenger aircraft characterised by take-off and landing runs of the order of 500 ft. over a 50-ft. obstacle, with correspondingly low take-off and landing speeds.

Turning to the problem of drag reduction by stabilising a laminar boundary layer through suction, Dr. Lachmann said that two basic methods had been tried out—distributed suction through porous material and suction through discrete sinks or slots. The latter were difficult to manufacture and maintain, but allowed a certain recovery of pressure. The lecturer, however, had introduced a method of sucking through discrete strips either porous or perforated.

DESIGN REQUIREMENTS FOR LAMINAR FLOW

The essential requirements to prevent transition from laminar to turbulent flow were: (i) the local surface roughness should be less than half the local boundary-layer displacement thickness; (ii) "waviness" of the skin should be less than 0·003 in. within a 3-in. curvature gauge; (iii) to prevent outflow, the pressure drop through the suction surface should be greater than spanwise or chordwise pressure variations on the surface, and (iv) the Reynolds number, based on the maximum component of the flow velocity perpendicular to the outer streamline and the boundary layer thickness, should be < 125. In addition, the suction surface should not add appreciably to structure weight and should not be difficult to maintain.

Dr. Lachmann then described two British patents for constructing a distributed-suction surface. In Patent No. 687,724, an inner skin of non-porous sheet and an outer porous sheet were interconnected by a lattice web, which subdivided the interspace into non-intercommunicating cells, each of which communicated through a non-return in the inner skin to a common suction chamber. In Patent No. 713,426, the surface comprised an inner load-carrying sheet having perforated recessed areas separated by exterior ridges milled from the inner sheet, and a continuous substantially unstressed porous outer surface stretched over the inner skin and attached to the ridges. The structural element comprised a corrugated sheet member and a second skin. These ducts were formed for the air sucked from the boundary layer within this sandwich panel.

Other forms of construction included porous strips, spaced at chordwise intervals, inserted in the outer skin as a sliding fit, with the shear flow in the outer skin by-passing the porous strip so as to leave it substantially unstressed; and a construction in which closely-spaced perforations in the outer continuous skin replaced the porous inserts, and where an element of suitable diffusing material could be inserted below the perforations to prevent local flow through the perforations. Since 1950, when these patents were applied for, much development had been carried out.

POROUS-PLASTIC SHEATHS

With orthodox methods of wing construction, the high degree of surface smoothness was difficult to achieve. The lecturer therefore looked forward to unconventional methods, leading to the use of pre-fabricated plastic-material porous sheaths bonded to the upper surface of a metal-sandwich panel and using the stress-carrying member as ducts.

Discussing methods of propulsion, Dr. Lachmann said that the power plant must be arranged to suit the special requirements in order to gain the full benefit of boundary-layer control. It must supply sufficient power to drive the suction blowers plus sufficient thrust to overcome the induced drag, body drag and any remaining wake drag when the suction blowers were not incorporated in the suction system. Although propeller turbines driving blowers offered the highest overall efficiencies, ducted fans seemed to offer the best solution taking into account the weight of the power plant and total fuel.

He thought it would be better to have a power plant to suit cruising conditions with best economy, supported by a light-weight second power plant to supply additional thrust for take-off. Reduction in size would enable the designer to choose unorthodox engine arrangements, such as dispersed components.

EXISTING ENGINE DESIGNS UNSUITABLE

Dr. Lachmann pointed out that existing ducted fan engines were too large for the laminar flow aircraft and said: "We may find ourselves unable to harvest the fruits of our labours in the aerodynamic field because of the lack of engines to power the aircraft of greatly reduced drag."

Discussing the improvements to be expected, the lecturer said that in the ideal case of an aircraft with complete laminar flow over the whole of its wetted surface, only one-quarter of the thrust of the "turbulent" aircraft would be required. Range would be about 150 per cent. greater and optimum cruising altitude 20 per cent. lower. With 50 per cent. laminar flow, the corresponding figures were: thrust reduction, 50 per cent.; range increase, 45 per cent.; and cruising altitude reduction, 14 per cent.

In concluding his lecture Dr. Lachmann expressed the view that the time had come for the emphasis of research to shift from academic treatment and wind-tunnel tests to flight trials and the development of practical engineering solutions.

The lecture was followed by a discussion in which it was mentioned that the Royal Aircraft Establishment had carried out flight trials during the past two years with a porous sleeve fitted to the upper surface of the wing of a jet aircraft. Full-chord laminar flow had been achieved, accompanied by a reduction in drag of more than 70 per cent.

GUIDED MISSILES*

THE GROUND-TO-AIR WEAPON

By G. W. H. Gardner, C.B.E., B.SC., M.I.MECH.E.†

After the war, study of the German achievements intensified interest in the potentiality of new guided-missile conceptions embodying up-to-date techniques, particularly radar. Such conceptions in the anti-aircraft role did not require visual sight of the target, nor the intervention of a human operator in order to guide the missiles.

The possibilities suggested a wide range of applications for attacking ships under or above the water line, for air-, ground- or ship-launched anti-aircraft weapons, and for attacking land or sea targets from land, sea or air.

THE GROUND-TO-AIR WEAPON

The requirement for the ground-to-air weapon may be for the defence of vulnerable points such as towns, factories and ports, or of large areas such as the whole of Britain. Attack may be launched at any height up to the maximum operating height of bombers within the next ten years (say, 60,000 ft.). Contemporary bombers fly at subsonic speeds but we have to be prepared to contend with supersonic attack in ten years' time, say, at 1,000 m.p.h., or nearly 17 miles per minute. Early warning by radar of the highest bombers is limited by the geometry of the system and this means a maximum warning time of about 10 minutes before bomb-release at 60,000 ft., and progressively less at lower heights. During this time the strength, height and direction of the raid must be assessed, a decision made to select and put into action appropriate defence units (including the acquisition of the targets by the necessary ground-based radar control system) and to launch the missiles in time to permit them to intercept and destroy their targets.

This at once emphasises some of the advantages and disadvantages of the guided missile relative to the manned interceptor aircraft. The missile is not subject to the physiological limitations of the human pilot, nor does it have to return to base. It can be provided with ability to accelerate more violently and can therefore take off, climb to height, and manoeuvre into position for the final phase of interception in a much shorter time. It can be fired in any weather conditions. On the other hand, the manned interceptor retains the benefit of supervisory human judgment at all stages of its flight and the versatility of mobility over a wide front. The need for effective guided missiles becomes more acute if a raid by atomic-bomb carriers is expected as it will then be necessary to destroy the bomber at an earlier time, preferably well out to sea, and with a high degree of certainty.

The war-head can be designed to produce a blast effect or to radiate fragments at very high velocity. A few pounds of high explosive would be adequate if there were a high chance of a direct hit. Since this is improbable it should instead carry sufficient high explosive (100 to 200 lb.) to ensure lethal damage from a near miss when the war-head is detonated by a proximity fuse. If the miss were greater than about 100 yards a prohibitive amount of explosive would be required. Accordingly, one must arrange to guide the missile to within that distance of the target. This is no mean task since the closing speed of target and missile may be about half a mile per second, and the target may be manœuvring.

GUIDING THE MISSILE

One possible guidance system provides for the missile to seek and home on the target. This can be done by illuminating the target with a radar beam transmitted by the missile (active homing) or by a source outside the missile (semi-active homing) and by fitting a seeker in the missile able to pick up and "look" towards the target which acts as the source of the reflected radar energy. A control system can then be devised to cause the missile to fly towards the target. But this system demands much complication within the missile.

A system which permits simpler missile equipment can be provided by continuous measurement by radar from the ground or ship of the positions of the target and the missile (Fig. 1). This information is fed into a computer which transmits to the missile, automatically by radio, steering instructions designed to ensure interception of the target.

Another method is to lock a narrow radar beam to the target and cause the missile to measure its own position in relation to the centre line of the beam and fly as close as possible to this line. This method is normally called "beam riding" (Fig. 2).

The missile must fly at very high speed. The sharp rise in drag in the region of the speed of sound can be surmounted by designing for low drag and by providing adequate thrust per unit frontal area. The "thermal barrier," however, presents a problem which becomes progressively more severe as speed rises. Air in the boundary layer (adjacent to the skin) which is accelerated to the speed of the missile is heated by friction and compressive forces; and the skin is thus heated by conduction. To a first approximation, the temperature rise in the stagnation regions of a body, in this instance due solely to compression of the air, can be expressed by the simple relation $\Delta T = (V/100)^2$, where ΔT is the temperature rise in deg. C. and V is the true air speed in m.p.h. Thus it is seen that while, at 100 m.p.h., ΔT is only 1 deg. C., it is 400 deg. C. at 2,000 m.p.h. The actual temperature rise experienced over most of the body is about $0{\cdot}85\ \Delta T$.

HIGH-TEMPERATURE MATERIALS

Clearly, if a missile or aeroplane is required to fly for more than a very short time at a speed much greater than twice the speed of sound, it will be necessary in the structure to avoid the use of aluminium alloys which lose strength and stiffness rapidly above 150 deg. C. and to use instead titanium alloys or possibly steel to withstand higher temperatures. Some alleviation of this difficulty can be obtained by insulation of the structure by, for example, the use of a carboniferous material having a high specific heat and high melting-point.

If to the aerodynamic heating effects are added temperature effects due to a rocket-motor combustion chamber and exit nozzle in which the flame temperature may be 2,500 deg. K., and to a liquid oxygen supply which may cause the temperature of parts of the missile to fall as low as 120 deg. K., the resultant engineering problems become truly formidable.

Fig. 3 shows that a typical rocket-propelled missile can travel two or three times as far by following indirect paths which minimise the time spent in the denser air at the lower heights. Choice of path is linked to choice of guidance; for example, beam riding would not permit either of the indirect paths shown.

The manœuvrability required at different heights must next be determined, so that sufficient lifting surface or wing area and adequate effectiveness of control can be provided for the greater heights, and sufficient strength for the lower heights. It may be readily seen that a simple pursuit-course interception, in which the missile at all times points straight towards the target, can demand accelerations which are impossible to provide. The demand can be limited or even caused to vanish after a time by adopting some such arbitrary law as $d\psi/dt = kd\theta/dt$, where ψ is the direction in which the missile is pointing and θ is the angle of the line of sight to the target. The constant k can be chosen to ensure that the path approximates to a constant-bearing collision course, and to reduce thereby the maximum acceleration demand. Acceleration capability must also be made to compete with any manoeuvring of the target and with impurities on the radar intelligence. All of these considerations together may demand the ability to manœuvre at between 10g and 20g.

With a knowledge of the war-head size, the speed, range, guidance method and control law, the propulsion system and aerodynamic form of the missile can be determined.

It is essential to seek an engine of very high thrust per unit frontal area, and of low specific

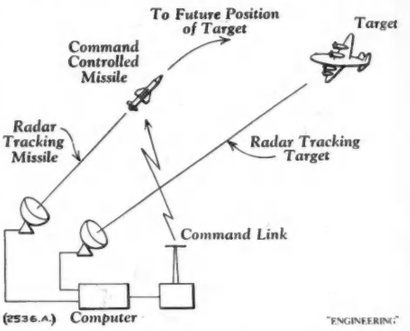


Fig. 1 Ground radar equipments measure the positions of the target and missile, and feed a computer which transmits steering instructions to the missile.

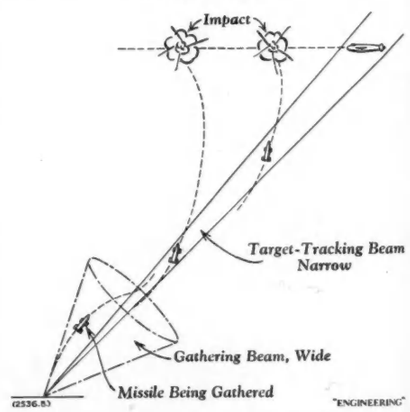


Fig. 2 "Beam riding": a narrow radar beam is locked to the target, and the missile measures its own position relative to the beam centre line, to which it flies as close as possible.

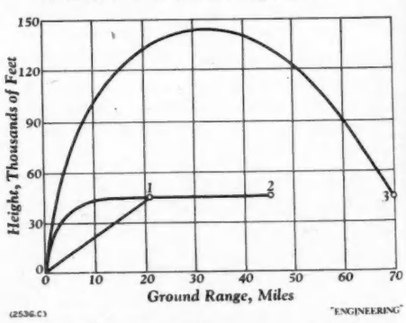


Fig. 3 Effects of trajectory on ground range.

* James Clayton Lecture delivered before the Institution of Mechanical Engineers on Friday, November 19. Abridged.

† Director-General of Technical Development (Air), Ministry of Supply.

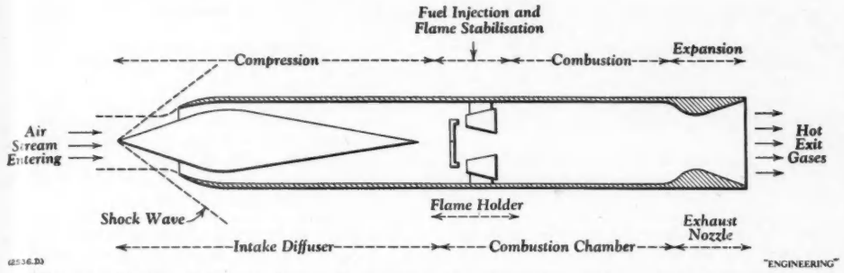


Fig. 4 Principle of the ram jet; its forward speed provides its own means of air compression.

weight and fuel consumption. A considerable excess of power must be provided to achieve very high acceleration.

Jet reaction motors are most suitable and a choice of three types is available: the rocket, the turbo-jet and the ram jet. The rocket motor is independent of the surrounding atmosphere in that the source of the oxygen necessary for combustion is carried in the rocket in solid or liquid form. In contrast the turbo-jet engine and the ram jet draw their oxygen from the atmosphere.

THE RAM JET

The ram jet, whose use is confined to high-speed flight, is notable for its simplicity (Fig. 4). The motor itself contains no moving parts. The function of the compressor in a turbo-jet engine is to raise the pressure of the incoming air to a value which will ensure good thermal efficiency. If, however, the turbo-jet is flying at twice the speed of sound at sea level the total head or ram pressure at the intake is 115 lb. per square inch abs., which is equivalent to a compression ratio of 7·8 to 1, assuming 100 per cent. intake efficiency. This process of compression by conversion of the high kinetic energy of the air usurps the functions of a mechanical compressor. If the compressor is dispensed with, it follows that no turbine is required and one arrives at the ram jet.

The ram jet is so inefficient at low speeds that it must be boosted to a speed approaching that of its designed operation by other means. For defensive missiles, this is not a handicap. Whatever propulsion motor is used, much more powerful boost motors giving thrust of the order of 20 to 30 times the weight of the missile are needed in addition to achieve an acceptable time from launching to operational speed.

The design of the air intake is a formidable problem. The air must be retarded, with minimum loss, from the flight speed to the internal flow speed at the entrance to the combustion region. At supersonic flight speed retardation can be caused by the creation at the intake entry of shock waves behind which the flow is subsonic; and thereafter a subsonic diffuser is used. At relatively low speeds, below Mach 1·5, one shock is sufficient, but above this speed a series of shocks is required to obtain efficient compression.

It is important to ensure that the characteristics of the air intake match those of the ram-jet combustion chamber. The air-swallowing capacity of the intake and its ability to compress the air efficiently are a function not only of the operating condition of the combustion chamber but also of the flight speed. Generally, an air intake which matches the combustion chamber at a given speed will be too large at a lower speed, and this gives rise to air spillage around the intake resulting in greatly increased drag and possible instability of flow, which in turn can have repercussions on the stability of combustion. In practice, the necessary compromise may be turned to good effect since the intake characteristics can be utilised to provide a major control of thrust. For higher speed flight and longer ranges where fuel economy is of greater importance, a variable intake will probably be required to provide optimum matching over the speed range, although this would detract from the inherent simplicity of the ram jet.

For a ram-jet-propelled missile of short range, it is preferable to save structure weight even at the expense of fuel economy. This fact, associated with the demand to get the greatest possible thrust from the ram jet, results in air-entry velocities to the combustion chamber of the order of between 200 and 300 ft. per second. This in turn implies that the drag coefficient of the flame-stabilising system of the combustion chamber must be kept small and that, in consequence, the degree of mixing given to the fuel and air mixture and the combustion products is much less than that permitted in a combustion chamber of a gas-turbine engine.

Furthermore, the intensity of heat release demanded of a ram-jet chamber (about 4×10^6 C.H.U. per cubic foot per hour per atmosphere) is greater than that required from turbine engines and the flow pattern of the entry air is also more susceptible to operating conditions. All these factors aggravate the difficulties associated with combustion. Moreover, the large interchange of kinetic, pressure, and thermal energies can sometimes lead to vibrations of amplitude sufficient to cause severe damage.

Usually, increase in flight performance demands more complexity and reduced reliability of the components of a missile or aeroplane. The ram jet is an exception. A ram jet capable of exerting, say, 100,000 h.p., can be built with less than a dozen moving parts and these are confined to the associated fuel-supply and control systems.

THE ROCKET MOTOR

The rocket motor is also simple in that, in the solid-propellant version, there are no moving parts at all, and in the liquid-fuel version the only moving parts are associated, as in the ram jet, with fuel supply and control. Aerodynamic problems associated with air swallowing are absent and motors can be tested up to full thrust on the ground with less extravagant facilities. In addition, because of its independence of the surrounding atmosphere, thrust at altitude is maintained; in fact, it increases somewhat as the atmospheric pressure falls. The chemical problems associated with rocket propulsion are, however, more acute and because the specific fuel consumption of rockets is many times greater than that of air-swallowing engines, great endeavour is made to employ higher flame temperatures, commonly about 2,500 deg. K. The employment of even higher temperatures would introduce more severe engineering problems arising from heat transfer from the gases to the structure.

The other main avenue for improvement is the use of propellants which produce gases of low molecular weight. In this instance the performance is inversely proportional to the square root of the molecular weight. Fuels now available can be pressed, extruded or cast in the solid form. Liquid-hydrocarbon fuels in association with highly concentrated hydrogen peroxide, liquid oxygen or nitric acid, are also used. Work on rocket motors has led to some most interesting mechanical developments. The development of the high-speed fuel pump and its associated bearings and seals due to Barske and described in the April 17, 1953, issue of *The Engineer* are worthy of special note. Another notable development is the successful welding and heat treatment of thin high-tensile-steel sheets in cylindrical form to provide casings for solid-propellant motors. Cylinders of 70-ton steel 0·063 in. thick have been made in this way to withstand a pressure of 1,500 lb. per square inch.

Table I indicates, by comparison with examples of engines of other types, the enormous thrust horse-power achievable with the rocket motor for an extremely low weight. The V2 liquid-fuel motor was remarkable in giving a thrust of

TABLE I.—*Some Performance Figures for Various Engines*

Engine	Thrust Horse-power	Specific Power, Thrust h.p. per lb. Weight of engine	Overhaul Period	Distance Travelled, Nautical Miles
V2 liquid-fuel rocket	627,000 (at Mach 5·2)	281	60 sec.	13
Aircraft turbo-jet:				
Present ..	8,700 (at Mach 0·9)	3·5	600 hr.	240,000
Future ..	35,000 (at Mach 1·5)	9·5	600 hr.	500,000
Aircraft piston	1,080	0·54	600 hr.	180,000
4-6-2 steam locomotive ..	1,800	0·009	18 months	130,000
Modern geared steam turbine (marine) ..	9,100	0·008	1 year	122,500
Geared steam turbine (R.M.S. *Queen Mary*)	104,000	0·0035	1 year	202,000

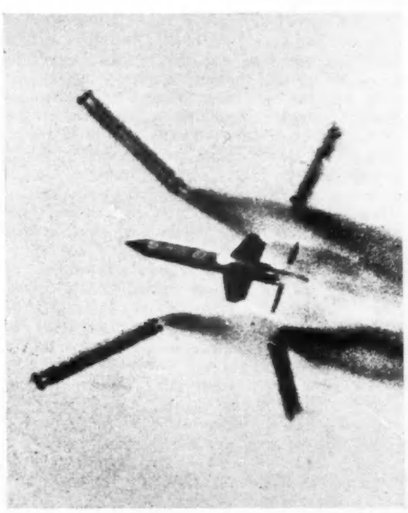


Fig. 5 A cluster of boost motors separating in flight after their fuel has been burnt.

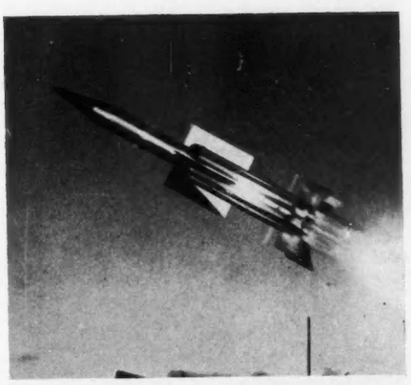


Fig. 6 A turn in any direction can be induced more quickly with a cruciform wing configuration (as shown here) than with a two-wing system as used on aircraft.

69,000 lb. for a dry weight of only 2,235 lb. complete. The speed reached by the missile after about 60 sec., when the motor had completed its task, was approximately 5,000 ft. per second (Mach 5·2).

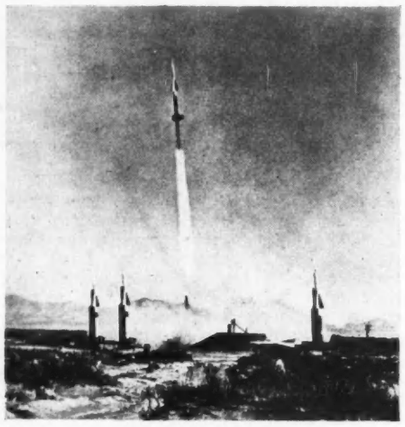


Fig. 7 Launching the U.S. Army missile " Nike."

Fig. 8 Nike engages the target, an unmanned bomber.

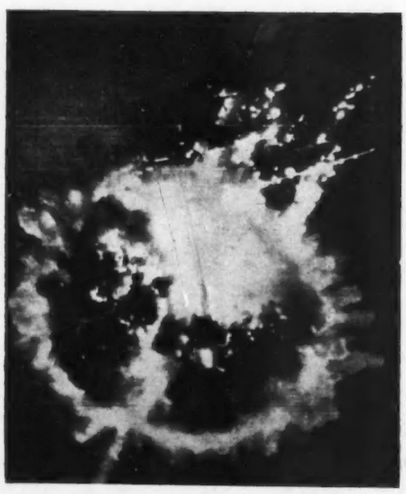


Fig. 9 Nike explodes on the target.

In the past ten years the thrust per unit area of British turbo-jet engines has been increased six times, their specific weight has been halved and their specific fuel consumption reduced by 20 per cent. Nevertheless, the turbo-jet does not yet compete with the rocket or ram jet as a means of propelling relatively short-range defensive missiles.

The rocket motor is most suitable for use as the boost to give an acceleration of, say, 25*g* for 2 sec., and to achieve a speed of about one and a half times the speed of sound.

It is efficient to discard the boost-motor carcase after the fuel is burnt, thereby reducing the weight and drag of the missile and a solid-fuel system fits this requirement most conveniently. Fig. 5, page 693, shows a cluster of boost motors after separation in flight.

The weight of the boost motors is of the same order as that of the missile, and since it is important to keep this weight as low as possible, great attention must be paid to the choice of propellant on the one hand and, on the other, to the reduction of deadweight consisting of the metal container, the nozzle, stabilising fins and other fittings. Work on methods of manufacture of very thin-walled tubes must be continued, including the possible use of plastics for this and for the nozzle.

There is little doubt that the rocket motor provides the best main propulsive unit for very short-range missiles or for those required to operate at very great heights. As the missile-range increases above about 20 miles the ram jet becomes more suitable, and at ranges greater than 100 miles the turbo-jet engine may have a place within limited height and speed boundaries.

PERFORMANCE AND CONTROL

To establish the aerodynamic form a vast amount of basic aerodynamic data is required on air forces exerted on aerofoils and bodies of different shapes and sizes over the whole speed, height and manoeuvrability range of the missile. Curves are then plotted from these data, and checked in wind tunnels or by full-flight experiment of the forces and moments generated on combinations of those components. Thrust curves for ram-jet and rocket motors can then be superimposed, chosen to ensure the required acceleration in straight flight and the excess thrust available to counter the additional drag induced in manoeuvres.

The cruciform wing system (Fig. 6) enables wing incidence to be applied simultaneously in two directions at right angles to one another and a turn can thereby be induced in any required direction with a lag depending only on the time required to apply wing incidence. The alternative two-wing system, commonly known as " twist-and-steer," first requires the missile to be banked until its wings lie in a plane at right angles to the required direction of turn and then requires the application of incidence.

Clearly, these alternative systems present the automatic-control designer with very different problems, not the least of which is the avoidance of the situation where an underdamped twist-and-steer system, trying to steer steadily towards its target, would necessitate frequent excursions of just less than 180 deg. bank.

The lift force which is generated on 1 sq. ft. of lifting surface in a free airstream at Mach 2 and at 10 deg. incidence is 2,400 lb. at sea level and, unfortunately, the centre of pressure changes with speed. It is necessary, therefore, to select the hinge line carefully so as to minimise the servo-power required to move a control of this kind very quickly. Even with care the peak requirements of a twist-and-steer control system for a missile of this kind can amount to 10 or 20 h.p.

Another effect arises if the control surface is mounted, as in most aeroplane controls, as a flap behind a fixed surface. When the control is deflected, the moment due to the lift force reacts on the fixed surface and causes it to twist and apply a moment on the missile in opposition to the control moment. Control reversal can result from this effect. This can be minimised by ensuring that the fixed surface is adequately stiff in torsion, or avoided by using all-moving control surfaces separate from any other fixed surface. Another most troublesome aero-elastic effect emerges in the form of body flexure. Modes of oscillation can be generated which are, unfortunately, detected by accelerometers and gyroscopes in the control system, and which can thereby induce unwanted missile movement.

It is becoming apparent that the guided missile is a complex servo-loop in which the reaction of the function of every component is felt through the loop and into which much spurious and disturbing information is injected, for example, by aero-elastic effects, radar " noise " and movement of the target.

The objective of the development of a ground-to-air missile is to arrive at a very high probability of producing the kind of result shown in Figs. 7 to 9. These depict the United States Army Ordnance missile " Nike " engaging a four-engined unmanned bomber target.

Development of guided missiles demands the same kind of preliminary work, system analysis, engine experimental work, wind-tunnel exploration, aerodynamic, structural and performance calculation and equipment experiment as the aeroplane. Some way must be found to avoid manufacturing, flying and each time destroying, the many hundreds or thousands of missiles which would be required to produce all the necessary flight information.

A wind tunnel with a working section 8 ft. square and capable of running continuously at two-and-a-half times the speed of sound would cost about £10,000,000. Furthermore, a vast supply of compressed air is required to test powerful air-swallowing engines. A modern propulsion-test plant capable of handling 300 lb. of air per second at sea level and of appropriate altitude operation would also cost about £10,000,000.

The use of Tridac (described in ENGINEERING, November 5—Ed. E.) for guided-missile problems will undoubtedly reduce the number of actual missiles which need to be flown for test.

Further equipment is required for simulating shock and vibration, acceleration, hot, cold, tropical, sea-spray, dust and other conditions.

Valuable information can be obtained by flight-testing missile components or by measuring effects in relatively cheap, often very small, purely experimental missiles or " test vehicles." For this purpose and for the inevitable full-scale missile tests, free flight facilities are required comprising tracts of country or sea areas, launching installations, instrumentation and communications. Some small ranges are used in Britain and a magnificent range has been created at Woomera in Australia.

The efficiency of flight-testing depends critically on instrumentation and, in particular, on reliable radio telemetering. On the ground, recording equipment with capacious memory can be fed with streams of information simultaneously through many radio channels during the course of the flight and these records can be examined later. The development of efficient recovery of experimental missiles would make an enormous contribution to speed and cost of research.

It is hard to imagine a more difficult engineering problem than that of developing a guided missile to a satisfactory degree of reliability. It must be designed to withstand a wide range of conditions during storage, transit and in operation. It is entirely automatic and the failure or partial failure of any component is likely to render the missile ineffective. It is not possible on the ground to simulate all conditions, and it is impossible to adjust anything once the missile is fired, after which it is difficult to find out the cause of a failure or even what has failed.

The missile is a complex of advanced aerodynamic, structural, propulsion, hydraulic, electronic and instrument techniques, and room for duplication of vital services can be provided only under great penalty. The required performances can be obtained only by refining and miniaturising until there is little reserve.

TESTING BALL BEARINGS AT HIGH ROTATIONAL SPEEDS

EXPERIMENTAL MACHINE FOR MEASURING TORQUE

By M. Graneek, B.ENG., A.M.I.E.E., *and H. L. Wunsch*, M.ENG., A.M.I.MECH.E.*

To obtain information about the performance of high-precision ball bearings of small diameter when operating at very high speeds, a machine has been developed which provides a continuous measurement of frictional torque of such bearings under defined axial and radial loading at speeds up to 50,000 r.p.m. Although the present paper is primarily concerned with the development of the testing machine, the ultimate object is the correlation of the dimensional accuracy of the bearings with overall performance. The torque-speed characteristics of particular types of bearing will also be investigated. The equipment, which is shown in Fig. 1, consists essentially of a high-speed driving unit, arrangements for applying variable axial and radial loads, and a sensitive recording torque meter.

HIGH-SPEED AIR BEARINGS

It was decided that the driving spindle for the ball bearing under test should run in a pair of air bearings. The reasons for this choice were, firstly, that it was intended to include vibration measurements in the performance test so that all auxiliary equipment should be as free from vibration as possible, and secondly, the ultimate high speeds envisaged (up to 100,000 r.p.m.). An air bearing, based on existing practice, was, therefore, developed in the laboratory and tested to determine its load capacity.†

As shown in Fig. 2, the journal bearings are each 1 in. long and 1 in. in diameter with a radial clearance between spindle and bearing of 0·001 in. Compressed air is supplied to the gap between the spindle and each bearing through three constrictions, 0·028 in. in diameter and $\frac{1}{8}$ in. long, displaced 120 deg. from each other round the circumference. For test purposes, radial load was applied symmetrically to the spindle by loading a pulley block in the position indicated in Fig. 2. Axial load was applied by deadweights, with the force acting through a bell-crank lever to the ball-ended spindle. Reaction to the axial load was provided by air pressure at the conical end of the spindle, compressed air being admitted through a constriction to the space between the end of the spindle and the thrust bearing.

AXIAL LOAD BALANCED BY AIR PRESSURE

When the axial load at the right-hand end of the spindle (Fig. 2) is increased, the spindle moves to the left and reduces the air gap at the conical surface. The increase in escapement resistance at the cone produces an increase in pressure at the end of the spindle, which automatically balances the axial load. This pressure is measured by a pressure gauge and the relation between it and axial load was determined by direct experiment.

This form of thrust bearing was used in preference to a constricted jet blowing on to the normal shaft end, because the conical design allows greater mechanical clearances, and it also provides a better pressure distribution with improved load capacity for a given size of bearing.

Tests on the experimental bearing showed that it was capable of supporting a symmetrical radial load of 40 lb. or an axial load of 30 lb. when the air-supply pressure was 60 lb. per square inch. The spindle was run at speeds up to 40,000 r.p.m., and the load capacity of the bearings was not appreciably affected by rotational speeds up to this value.

HIGH-SPEED MOTOR WITH AIR BEARINGS

The driving unit is a 3-phase, 2-pole, high-frequency motor supplied from a variable-speed motor-alternator set. Initial tests were carried out with a water-cooled motor, designed by the Hoffmann Manufacturing Company, Limited, New-street, Chelmsford, Essex, which incorporated a stator-rotor unit made by the British Thomson-Houston Company, Limited, Rugby. This unit was fitted with precision ball bearings. For the reasons stated above it was considered desirable not to use ball bearings in the final design and a new motor was developed in the laboratory incorporating a similar stator-rotor unit with air bearings.

The journal and thrust bearings in the motor are similar to those previously described. Most of the exhaust air from the bearings is made to pass over the stator laminations before being released to atmosphere and thus provides adequate cooling. This motor has been run continuously for 3 hours at 60,000 r.p.m. on no load with a maximum temperature rise of 26 deg. C., as measured by a thermocouple attached to the stator windings.

In order to obtain some design data for the thrust bearings, models of the two types of conical bearing at the driving end and non-driving end of the shaft were made. In each case the displacement of the model shaft was measured for various values of axial load and a combined graph of the results is given in Fig. 3. The abscissa origin corresponds to the axial position of the shaft when the shaft and bearing cones at the non-driving end are in contact, and it is assumed that there is a total axial clearance of 0·020 in.

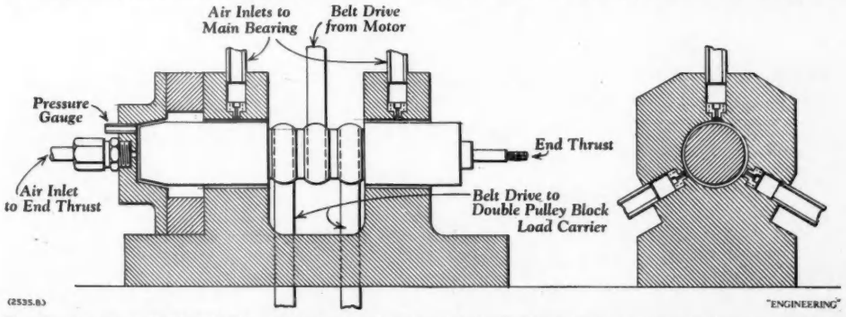


Fig. 2 On account of the high speeds involved and to eliminate vibration from the auxiliary apparatus, air bearings, as shown here, were used to carry the test-bearing driving spindle.

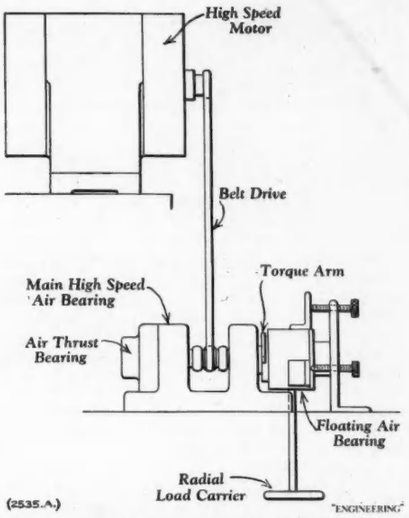


Fig. 1 Equipment for investigating the performance of small precision ball bearings under axial and radial loading at speeds up to 50,000 r.p.m.

THRUST BEARING DATA

The difference between the ordinates, corresponding to any displacement of the shaft, indicates the axial load which the bearings will withstand, and the point of intersection of the two curves indicates the neutral position of the shaft, that is with no external axial load. Provision must be made for a maximum radial movement of the shaft of $\pm$ 0·001 in. (the clearance at the journal bearings so that axial movement of the shaft cannot take place in the regions between the origins of the two curves and displacements of 0·004 in. from these points). (The cone apex angle is 28 deg. for each bearing and tan 14 deg. = 0·25.)

The working range is, therefore, that shown between the dotted lines, and the safe maximum axial loads which may be applied to the motor, as measured from the graph, are 21 lb. inwards and 13 lb. outwards. The motor is capable of withstanding a radial load at the driving pulley of 20 lb., determined experimentally. The new motor fitted with air bearings can be seen at the top of Fig. 8.

The motor is fitted with a crowned pulley of diameter $\frac{7}{8}$ in. and width $\frac{3}{8}$ in., the amount of radial crowning being $\frac{1}{64}$ in. An endless belt, $\frac{1}{16}$ in. wide and $\frac{1}{32}$ in. thick, made of pure tussah silk impregnated with linseed-oil dressing is used to transmit the drive to the spindle located vertically below the motor. This type of belt has been found to operate very satisfactorily at spindle speeds up to 50,000 r.p.m., that is, the maximum speed achieved to date.

At these high speeds the shafts must be dynamically balanced to a high degree of accuracy, and for this purpose an electronic dynamic-balancing machine has been used, capable of detecting an amount of unbalance equal to $\frac{W}{50{,}000}$ ounce-inches, where W is the weight of the shaft in ounces.

ALIGNMENT BY FLOATING BEARING

The inner race of the test bearing is held in position on the end of the high-speed spindle by a nut. The outer race is clamped axially in a housing which forms the inner of a "floating" air bearing. The bush of this air bearing has two rows of three inlet holes spaced 120 deg. apart; two of these inlets appear in Fig. 4. Three angle brackets are fixed to the air-bearing outer and the polished face of each bracket bears against a ball-ended stop, the upper one being shown in Fig. 4. In this way the air-bearing outer is free to move in a plane at right angles to the spindle axis, and this permits radial self-

* Mechanisms and Metrology Division, Department of Scientific and Industrial Research, Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.

† Mueller, P. M. "Air lubricated bearings." *Product Engineering*, August 1951, pages 112-115.

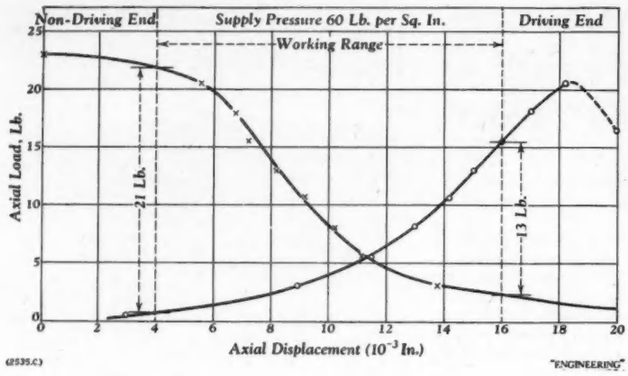


Fig. 3 Graph giving design data for thrust bearings. It was constructed from results obtained by testing models of the conical bearings to be employed.

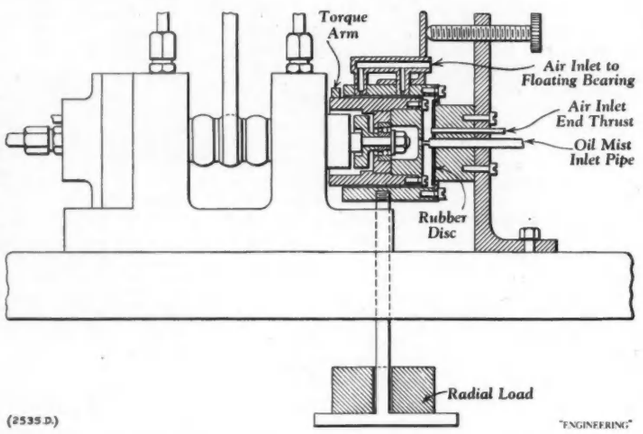


Fig. 4 Radial self-alignment of the inner and outer races of the test bearing are made possible by the provision of a "floating" air bearing. The weight carrier for the application of radial load is also shown here.

alignment of the inner and outer races of the test bearing in the machine.

Radial load can be applied to the test bearing by the weight carrier, also shown in Fig. 4. Axial load is applied by admitting air under pressure to the space containing the blanked-off end of the test-bearing outer housing, the axial load being measured by the calibrated pressure gauge at the conical end of the spindle, as described earlier. Freedom of movement of the outer housing and adequate sealing of the compressed air providing the axial load is ensured by the use of the rubber disc shown in this diagram. By these means both radial and axial loads can be applied to the test bearing without imposing any frictional constraint on the outer race. Provision is also made for the supply of oil-fog lubrication to the ball bearing.

TORQUE METER

Frictional torque in the rotating ball bearing is detected and measured with the aid of a torque arm (Fig. 5) fixed to the outer-race housing. A photo-cell pick-up unit is arranged at one end of the arm to detect any movement of the arm produced by frictional torque in the test bearing. The photo-cell signal is amplified by a conventional electronic amplifier and fed back to a moving coil wound on a copper former which is fixed to the opposite end of the torque arm to the pick-up. The coil moves in the field of a permanent magnet. The coil former has been made rectangular in plan, so that some axial movement of the torque arm is permissible while a small magnetic air gap is retained.

With the closed-loop system described above the electro-magnetic pull of the coil continuously balances the external torques applied to the inner of the floating air bearing, and the current in the coil bears a linear relationship to that torque since the magnetic field strength is constant. The coil is connected in series with a 25-milliampere recorder, full-scale deflection of which corresponds to a torque of 20 gm.-cm. Errors due to friction in the floating air bearing were estimated to be less than 0·1 gm.-cm.

The torque meter was calibrated by a preliminary test in which weights were placed on a carrier supported on a knife edge at a known distance from the centre of rotation of the torque arm. Damping is provided by an oil dashpot, as shown in Fig. 5.

ZERO ADJUSTMENT

Zero setting is performed by adjusting the position of a small rider weight. It was found necessary in practice to adjust the zero when the test bearing was changed or whenever radial load was altered. The main reason for this is that the radial load, which acts in a vertical line through the geometrical centre of the floating air-bearing bore, is not generally in line with the reaction to the radial load, which acts vertically upwards through the geometrical centre of the test-bearing inner race.

Eccentricity of the inner race relative to the centre of rotation of the driving spindle is unimportant in this respect as tests are normally carried out at high speeds of rotation and average values of frictional torque measured over several seconds are usually required. Eccentricity of the outer race relative to the air bearing does, however, produce an important effect. It is of interest to note that a radial load of 4 lb. in conjunction with an overall average eccentricity of 0·0002 in. would produce a zero error of torque reading equivalent to about 1 gm.-cm. For this reason it is necessary to check the zero reading between tests.

This is done by holding the test bearing in a fixed position with the aid of a simple fixture which clips over the driving spindle, tapping the spindle lightly to reduce static friction in the test bearing and noting the reading on the torque recorder. The process is repeated at several different positions of azimuth of the test bearing and an average value of torque obtained on the recorder. This average value is made equal to zero by adjustment of the rider weight. The accuracy of zero setting by this method is considered to be within ± 0·1 gm.-cm. of the true setting.

SPEED MEASUREMENT AND SAFETY DEVICES

Rotational speed of the test bearing is measured photo-electrically. One half of the circumference of the driving spindle over a short axial length is painted black and light from a small-lamp source is reflected from this part of the shaft on to a photocell; the electrical impulses picked up (one per revolution of the shaft) are transmitted to a frequency monitor, which can be suitably calibrated in revolutions per minute.

The rotating parts of the machine are totally enclosed in an expanded-metal frame to protect personnel. To prevent damage to the equipment in case of air-supply failure a microswitch operated by a Bourdon tube is made to open the main contactor supplying the motor-alternator set and so stop the high-speed motor if the air-supply pressure falls below about 80 per cent. of its rated value. A small relay is connected in series with the torque-meter coil and recorder to provide protection for the equipment in the event of excess friction being developed in the test bearing. Operation of this relay due to excess frictional torque also stops the high-speed motor by opening the main contactor.

TORQUE-SPEED CURVES

A series of preliminary checks have been carried out, mainly to test the machine, but also to obtain some information on the torque-speed characteristics of a particular type of ball bearing—a precision angular-contact bearing, 5 mm. in bore.

The test procedure consists in giving the bearing five minutes of oil-fog lubrication and then running it for one hour under the selected load and speed conditions. The value of frictional torque reached at the end of the hour

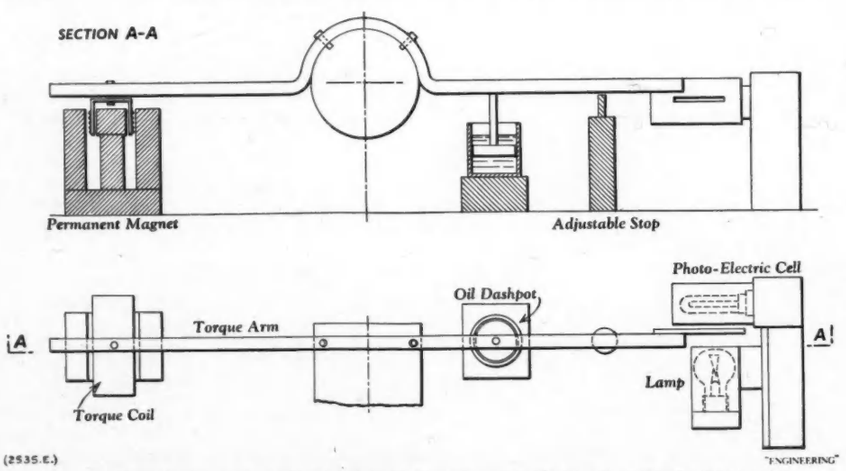


Fig. 5 Torque arm and photo-electric cell for measuring frictional torque in the bearing.

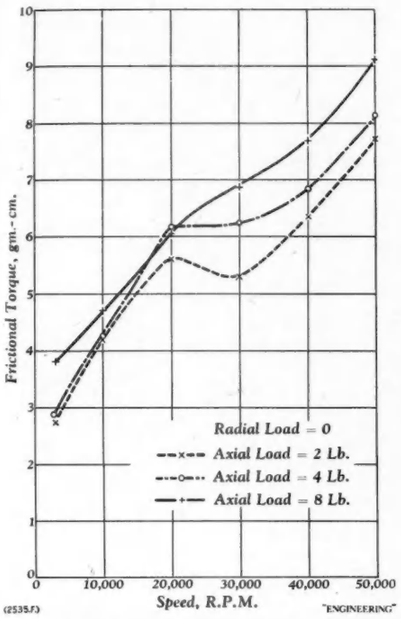


Fig. 6 Torque-speed curve for 5-mm. bore precision ball bearing with constant radial load.

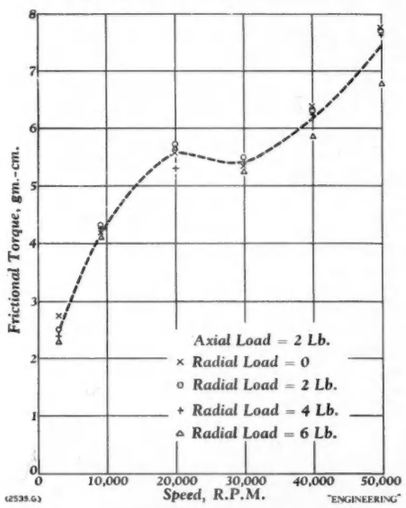


Fig. 7 Torque-speed curve for 5-mm. bore precision ball bearing with constant axial load.

is then taken as the value for the particular conditions. Two tests were carried out for each set of conditions and the results obtained were found to agree closely in the majority of cases.

Figs. 6 and 7 show the torque-speed curves for constant radial and constant axial load, respectively, the results in each case being the mean values for the five bearings tested. It is too early yet to draw any firm conclusions from these results, but it would appear that, for this type of bearing, the axial load has a greater effect on frictional torque than the radial load, within the load limits applied. It is hoped to extend this work in the future by employing grease lubrication, with tests on 5-mm. and larger bearings, but a very considerable number of results will have to be obtained before any definite conclusions can be drawn.

SCOPE OF TEST MACHINE

The machine in its present form, photographs of which are shown in Figs. 8 and 9, is capable of testing ball bearings of 5-mm. or 10-mm. bore at speeds up to 50,000 r.p.m. The maximum

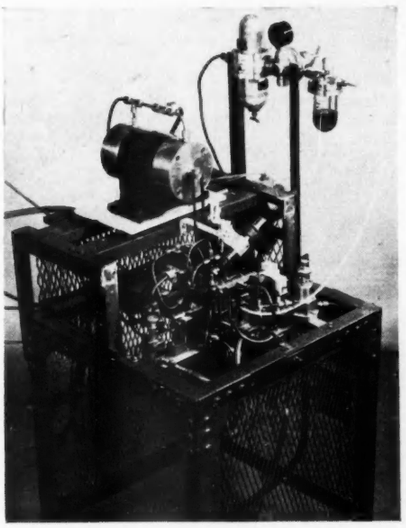


Fig. 8 Test machine developed for the investigation. It incorporates an air-cooled motor which runs in air bearings and provides the high-speed drive required.

values of radial and axial load which can be applied to the test bearing have been found to be about 8 lb. and 10 lb., respectively. The total air consumption is 13 cub. ft. of free air per minute and the supply pressure 60 lb. per square inch.

The design of the apparatus is now being modified to increase the range of test conditions so that the scope of the experimental work can be extended in respect of both load and speed. In order to carry this out it is intended to enlarge the projected area of the air bearings so that both radial and axial loads of 20 lb. can be applied to the ball bearing under test. A new motor, with a smaller stator-rotor unit, has been designed, with which it is hoped to increase the speed range up to 100,000 r.p.m.

Preliminary trials are also being carried out with a barium-titanate piezo-electric pick-up in an attempt to measure vibration in the test bearing.

The authors wish to express their thanks to Mr. W. H. Swayne of the Hoffmann Manufacturing Company; valuable assistance was also received from their colleague, Mr. T. W. Aitchison, who designed the electronic amplifiers used with the torque meter and speed-measuring devices, and advised on the use of pick-ups.

The work described above has been carried out under Admiralty contract in the Mechanisms and Metrology Division of the Mechanical Engineering Research Laboratory, as part of the research programme of the Mechanical Engineering Research Board. It is published by permission of the Director of the Laboratory.

* * *

CONTROL OF INDOOR TEMPERATURE

Device Takes Account of External Conditions

The Thermocontrol Installations Company, Limited, 2-10 Valentine-place, Blackfriars-road, London, S.E.1, have introduced a device called an electronic variator, which is designed to maintain a steady temperature within a building, independent of climatic variations. Two models are available, one for low-pressure and the other for high-pressure hot-water systems.

The equipment consists of two detecting elements employing thermistors, one in the hot system, and the other outside the building, together with a central control unit. The resistance-temperature characteristics of the external detector are designed to supply a signal to the control unit, which varies with the climatic conditions. This signal is fed to a resistance bridge circuit and the resulting change used to reset the operating temperature of the element immersed in the hot water. This in turn actuates a balance relay which controls either the mixing valve in a simple water circuit, or the combustion conditions in the main boiler when other systems are used.

Advantages claimed for the equipment are that there are no moving parts to wear out; that response is immediate; that there is no over-swing and that it can be adjusted after installation to suit the particular needs of any building. It is also claimed that overheating can be avoided, with a consequent economy in fuel.

* * *

EXTENSIONS TO OIL REFINERY

It has been announced that work has now been completed on the Weaste (Lancashire) Refinery of Berry Wiggins and Company, Limited. The principal contractor has been Head, Wrightson Processes, Limited, Teesdale House, 24-26 Baltic-street, London, E.C.1, who designed and erected the plant. The original refinery installation was built in the early 1930's, complete with a tank farm and pipeline connections to the jetty on the Manchester Ship Canal.

The latest extension has stepped up the capacity of the plant by 500 barrels per day, and resiting of parts of the original installation was necessary to make provision for the new units due to the restricted space available and the difficult nature of the ground.

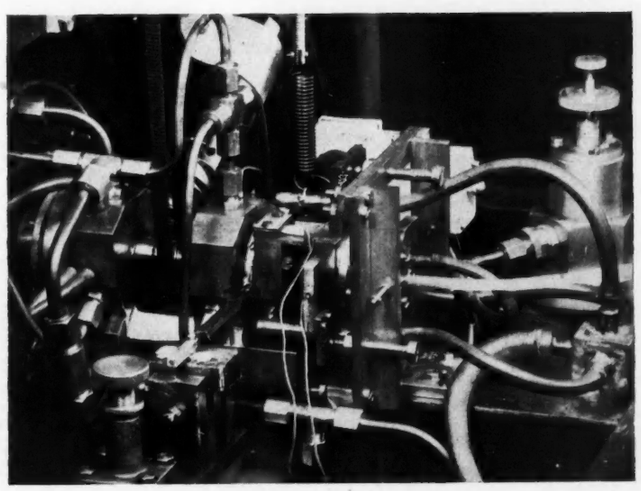
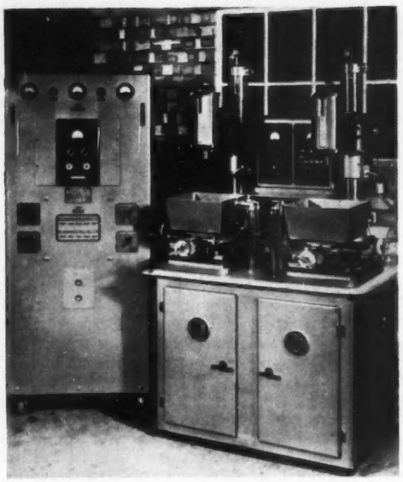


Fig. 9 Close-up view of machine. It is capable of testing bearings of 5- and 10-mm. bore, and maximum radial and axial loads of 8 and 10 lb. can be applied.



The Sparcatron machine, shown here as a twin-head model, uses electric sparks at high frequency for cutting hard metals.

CUTTING HARD METALS

Electric-Spark Process in New Heavy-Duty Machine

The "Sparcatron" process for cutting hard metals, which has been described in ENGINEERING (vol. 174, page 121, 1952), involves the use of electric sparks, produced by the discharge of a condenser. The sparks, at frequencies ranging from 12,000 to 100,000 per second, are directed at the workpiece, which is immersed in a bath of dielectric liquid, and the liquid is pump-circulated so that the particles which are produced when the sparks strike the work are carried away. The dielectric liquid is collected in a sump, where it is settled and filtered before re-use. By moving the workpiece or the electrode, or both, any desired shape can be produced.

The Sparcatron technique is readily applicable to the machining of dies and other components of hardened steel, and it is equally suitable for cutting hard metals and alloys which cannot be worked by normal cutting tools. Similarly, it can be used for producing shapes in hard metals which cannot readily be ground by abrasive wheels. Spark cutting can be used for working to fine limits, and it does not cause any loss of hardness in any alloy which would be affected by heat, since the heat of the spark, though intense, is extremely localised, and of very short duration.

SINGLE- OR TWIN-HEADED VERSIONS

Up to the present only one size of machine has been available, but a new heavy-duty model is now in production. It is identical in principle with the earlier one, but is designed for use with electrodes of heavier section, and has been modified in detail to enable larger work to be undertaken and at the same time to retain the fine-limit characteristics of the smaller machine. The new machine is available either as a single unit, with one electrode head and a compound worktable, or as a twin unit with two heads and two worktables mounted on a cabinet base. The twin unit can be worked by one operator, with the two electrode heads and the two tables under independent control.

The basic element of the machine is the electrode head, which is mounted on a 4-in. diameter column. It is servo-controlled and runs on V ball-bearing slides. A cable-type counterbalance ensures smooth movement, and there is a location slide for accurate re-setting. The compound worktable, on which the dielectric liquid bath is mounted, has fine adjustment for movement in both directions, and is designed for use with Johansson blocks if required. A motor-driven pump, with a settling tank and filter, is located in the cabinet base of the machine. Control gear is housed in a cabinet located at the side of the machine, and in the case of a twin unit an auxiliary control panel, for the second electrode head, is mounted on the cabinet base between the columns. Two independently-operated pumps, settling tanks and filters are also provided for the twin-unit machine, and either or both of the heads can be used as required. A further two or more heads can be fitted.

The Sparcatron machine is made by Impregnated Diamond Products, Ltd., under licence from Sparcatron, Ltd., and is marketed in Great Britain and Northern Ireland by Burton Griffiths and Co., Ltd., Mackadown Lane, Kitts Green, Birmingham 33, who will be displaying the machine at an exhibition announced on another page in this issue.

A RANGE OF TOOLROOM MACHINES

ENGRAVING, DIE-SINKING, PROFILING AND TOOL-GRINDING

The range of toolroom equipment made by Friedrich Deckel, Munich 25, Germany, and marketed in Great Britain and Northern Ireland by Burton Griffiths and Company, Limited, Mackadown-lane, Kitts Green, Birmingham 33, includes a variety of pantograph die-sinking, universal tool-milling, profiling and cutter-grinding machines. These machines are to appear in an exhibition, announced on another page in this issue, which has been arranged by the United Kingdom agents.

THREE-DIMENSIONAL COPYING

The die-sinking machine shown in Fig. 1 is available in two models, both of which use a pantograph mechanism to reproduce the contours of a master or pattern on a workpiece, clamped to the table under the cutter head. The two models are basically the same, but the worktable area is slightly larger on one machine, the respective clamping areas being 9 in. by 25½ in. and 9¾ in. by 27½ in. The master clamping table has an area of 17 in. by 23½ in. on both models. The cutter spindle can be arranged to reproduce the movements of a stylus working over the master in a direct ratio of 1 to 1, or, with extra equipment, to enlarge or reduce the movements in ratios of 1 to 1½, 1 to 2, 1 to 2½, 1 to 3, or 1 to 4. The two tables are generally at approximately the same height when cutting is in progress, but both can be independently adjusted vertically. The worktable can also be adjusted longitudinally and transversely to enable the workpiece to be positioned accurately relative to the master. A further feature of the two tables is that they can be so arranged that independent vertical adjustment is possible, but all longitudinal and transverse movements are coupled. The cutting area can thus be extended by moving the master and workpiece and at the same time retaining the exact relationship established at the start of the cut. For roughing-out at 1 to 1 ratio the pantograph mechanism can be locked and rough cuts made by moving the tables.

The two machines can be fitted with rough-milling spindles with speeds from 120 to 800 r.p.m., and 60 to 400 r.p.m. respectively. Finish-milling spindles have speeds ranging from 400 to 10,000 r.p.m. on the smaller machine and 350 to 10,000 r.p.m. on the larger. A two-speed, pole-change electric motor, with speeds of 1,400 and 2,800 r.p.m. provides the power for both machines. Powered movement of the vertical saddle, with an independent motor, is provided on the larger machine only. Both machines can be provided with a variety of extra fittings, such as optical equipment, a reducing and enlarging attachment, circular forming and horizontal routing attachments, and circular tables.

UNIVERSAL TOOL MILLING

Two machines are made for universal tool-milling work; they are illustrated in Figs. 2 and 3. The machine shown in Fig. 2 has a horizontal cutter spindle mounted in a ram-type slide, which is adjustable longitudinally by means of a hand-wheel. The worktable can be power-traversed in eight different directions under the control of a single lever. The appropriate setting of this lever causes the table to travel to the left or right horizontally, up or down vertically, or in any one of four diagonal directions at 45 deg. There is a six-speed gearbox, speeds being selected by two gear-shift levers, and a two-speed pole-

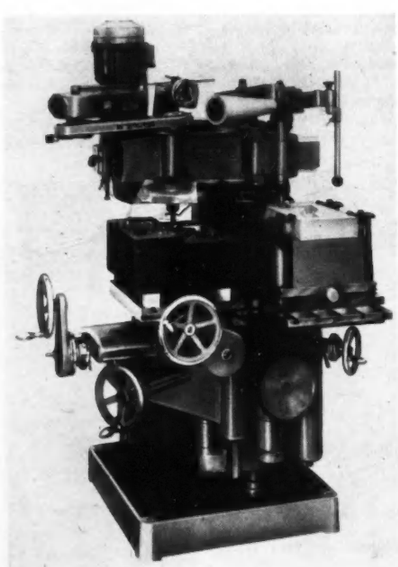


Fig. 1 Three-dimensional die-sinking machine employing a pantograph mechanism.

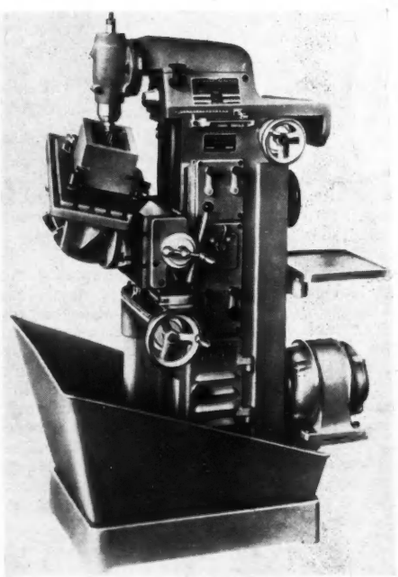


Fig. 2 Universal tool-milling machine, shown with vertical milling head.

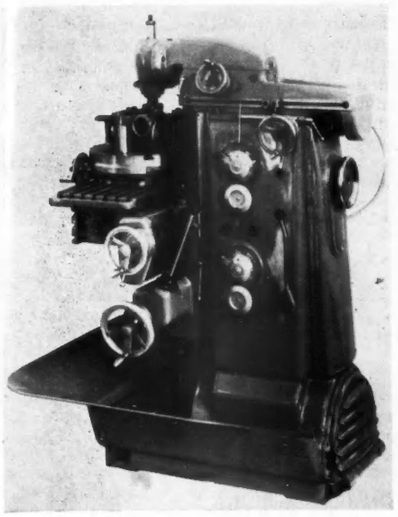


Fig. 3 Universal tool-milling machine, with power feed to all motions.

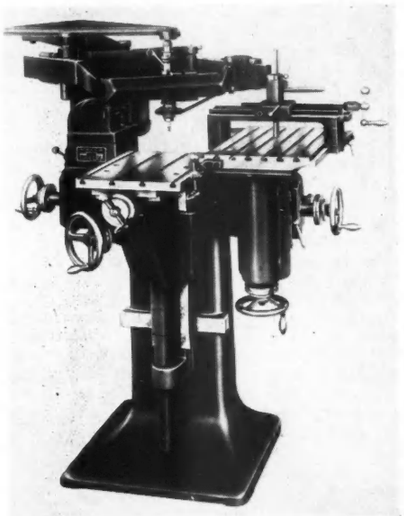


Fig. 4 Pantograph profiling and engraving machine, fitted with rough-milling attachment.

change motor drive, giving a range of 12 speeds from 60 to 1,200 r.p.m. A similar arrangement is provided for the power feed to the worktable, and 16 geometrically-increasing speeds are available, with a maximum feed rate of 19 in. per minute.

By the use of additional equipment the machine can be used as a vertical miller or a slotting machine. For vertical milling two different heads are available. The first of these is mounted on the upper-spindle ram ways, and engages with the machine gearing to provide twelve speeds, selected through the main gearbox, from 95 to 1,900 r.p.m. The second vertical milling head is mounted in the same way but incorporates a separate high-speed motor, which drives through V-belts and pulleys to give spindle speeds from 1,900 to 6,000 r.p.m. Both the vertical milling heads can be swivelled for angular milling, the first through 360 deg. and the second up to 45 deg. in either direction. For slotting an attachment is available which fits on top of the spindle ram and connects with the main drive to give twelve speeds from 24 to 475 strokes per minute. The stroke length can be varied as desired up to a maximum of 3¼ in., and the head can be swivelled through 360 deg.

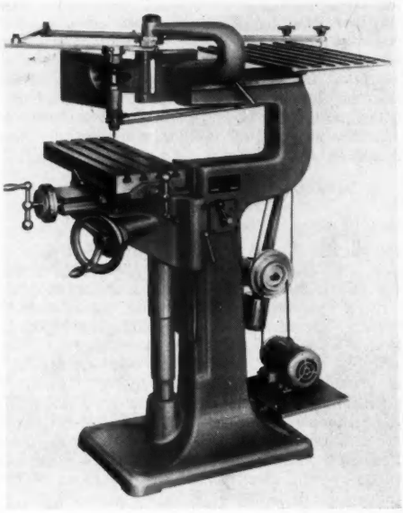


Fig. 5 Letter engraving machine as used for flat work.

A spiral milling attachment is also available; it has an indexing head and can be swivelled up to 45 deg. in either direction. There is also a range of work-holding and indexing fixtures and a variety of cutting tools, clamps and gauges which can be supplied as required.

The machine shown in Fig. 3 is very similar to that illustrated in Fig. 2, but it has greater capacity and incorporates several refinements. The cutter spindle is axially adjustable in the spindle head and power feed, in two directions, is provided for the head. The range of speeds is increased in this machine, the selection being by graduated dials. There are 18 spindle speeds, ranging from 40 to 2,000 r.p.m., with a ratio of 1·26 to 1 between consecutive speeds. Power feed is available for all motions, that is, vertical and horizontal table movement, and horizontal movement of the spindle head. Dial-type selectors are used, and the 18 speeds available range from 0·315 in. to 15·8 in. per minute. Table-feed motion is controlled by a single lever, and a separate lever is provided for the spindle-head feed. Rapid power-traverse at 47 in. per minute can be used in all feed directions.

The range of attachments available on this machine is similar to that on the machine shown in Fig. 2, but there is also a special boring head which, like the vertical milling head, can be swivelled through 360 deg. It is also arranged for vertical movement up to 4 in. through a rack and pinion. The boring head has the same range of speeds as the horizontal cutter spindle, and three feed rates, 0·0012 in., 0·0024 in. and 0·0048 in. per spindle revolution. The depth of bore can be controlled by vernier or dial gauge as required, and provision has been made for automatic tripping of the boring feed.

PANTOGRAPH PROFILING

Fig. 4 shows one of two machines designed for profile milling or engraving. Both machines are identical in principle, and differ only in capacity. The table sizes are the same for both machines, the copy or pattern table being 12⅝ in. by 17¾ in. and the worktable 7⅞ in. by 13¾ in. Vertical and longitudinal adjustment are provided for the copy table, while that which carries the work can be adjusted vertically, longitudinally and transversely. The lighter machine is powered by a ¼-h.p. motor, which drives the cutter spindle through a cord and pulleys, and a ½-h.p. motor, driving through V-belts and pulleys, is provided on the larger machine. The latter can handle work up to 550 lb. in weight, and can be provided with a rough-milling attachment for the removal of relatively large amounts of stock. With this attachment the copying stylus is held in a bridge-type cross-slide over the pattern, and movement is controlled by feed screws. This attachment is shown in Fig. 4. The spindle speeds available are 1,900 to 15,000 r.p.m. in the lighter machine and 475 to 9,500 r.p.m. in the heavier.

The pantograph system of both machines is hinged at its support, and profiling or engraving can thus be performed in three dimensions. The cutter spindle can be caused to reproduce the movement of the tracing stylus in a selected ratio, reduced or enlarged, between 1½ to 1 and 10 to 1. Work-vices, indexing work-holders, circular tables and copy-holders for letter engraving are available as extras for both machines.

LETTER ENGRAVING

The machine shown in Fig. 5 is similar in principle to the pantograph profiling machine described above, but it is designed for two-dimensional work. It is one of two models, which differ only in size. The machine shown in the illustration has a clamping area of 19¾ in. by 7¾ in. on the worktable, and 21½ in. by 12¾ in. on the copy-holder table. The worktable can be adjusted vertically and in two directions horizontally, and the copy-holder table, which is attached to the pantograph carrier arm, can be adjusted longitudinally with the arm, and also swivelled through 90 deg. The column supporting the pantograph is " deep-throated " to allow large components to be clamped on the worktable. The cutter spindle is driven by a ¼-h.p. motor through cords and pulleys. It has a speed range of 1,900 to 15,000 r.p.m., and a vertical adjustment of 0·118 in. coarse and 0·039 in. fine. The ratios available range from 1 to 1 to 50 to 1. The machine can be equipped with attachments for engraving on cylindrical, conical, convex or concave surfaces from flat masters, and can be used with an electro-marking head for marking hardened components.

UNIVERSAL TOOL-GRINDING

The tool grinder shown in Fig. 6 will, with a small number of extra attachments, handle the

Fig. 6 Universal tool-grinding machine.

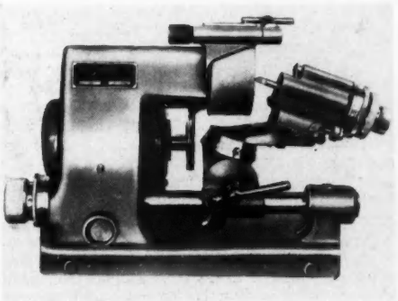


Fig. 7 Single-lip cutter grinder.

grinding of most of the tools used in a toolroom or machine shop. Wet-grinding equipment for grinding tungsten-carbide tipped tools with a diamond wheel can also be used on this machine.

The machine comprises a fixed grinding-spindle head and a work head mounted on slideways. A cabinet base, which carries both heads, houses the driving motor, electrical equipment and an exhaust fan for removing the dust from the grinding head. The work head is an adjustable work fixture and index head, with a No. 4 Morse taper an a collet chuck. It has a longitudinal travel of 10·2 in. and a transverse movement of 7·87 in., with provision for fine adjustment through the cross-slide of 1·97 in. Vertical adjustment of 1·97 in. is also possible. The maximum diameter of cutter which can be accommodated between centres is 5·1 in.; cutters up to 12·6 in. diameter can be fly-mounted.

The standard machine will grind serrated and relieved-tooth milling cutters, counterbores, cylindrical and taper reamers, taps, and other forms of cutting tool. A spiral-grinding attachment is available for spiral-fluted tools, and also for grinding the lands of small and medium-sized steep-spiral milling cutters. A lead tester with vernier scale and feeler-rod carrier is available for checking leads on spiral-fluted tools. For the face-relieving of boring, counterboring and screw-machine tools a relief-grinding attachment is available. An additional tilting plate can also be fitted to increase the angular setting when grinding heavily-tapered tools. A wheel-dressing attachment can be supplied for profiling the wheel to any desired angular, convex or concave shape as required.

SINGLE-LIP CUTTER-GRINDING MACHINE

A single-lip cutter-grinding machine, complementary to the engraving and profiling machines described above is shown in Fig. 7; it is arranged for bench-mounting, but can also be supplied with a cabinet base and dust-extraction equipment. The machine has a fixed grinding head and a universally-adjustable work-carrier. The grinding spindle runs at 4,500 r.p.m. and is driven by a rear-mounted motor through a cord and pulleys. The work-carrier head slides longitudinally on a tubular guide, and can be indexed in a circular motion about this guide. Provision is made for mounting the complete cutter-spindle assembly of each member of the range of engraving and profiling machines, in order that the cutter may be ground in position on the spindle.

NEW EQUIPMENT FOR RADIOTHERAPY

ORTHOTRON AND BETATRON INSTALLED AT MANCHESTER

It is often necessary in the radiotherapeutic treatment of cancer to deliver an adequate dose to a deep-seated tumour. In such cases the greater the penetration of the rays the fewer are the beams that have to be used or the dose, which each beam applies to the skin, can be reduced. These conditions can best be fulfilled by the employment of high voltages, since they render it easier for an adequate voltage to be delivered at a depth. High voltages also enable the maximum dose to be produced some distance below the surface of the skin (about 1 cm. at 4 million electron volts) thus reducing undesirable effects. Further, the amount of scattered radiation is decreased and the bones and soft tissues absorb the rays about equally, a matter of some importance in radiotherapy. On the other hand, extremely high energy radiation may lead to difficulties owing to the increased dose given to the skin at the point where the beam leaves the patient's body. The optimum energy is therefore not sharply defined. These questions are now being investigated in the Radiotherapy Department of the Christie Hospital, Manchester under Dr. Ralston Paterson where a 4-million electron volt travelling-wave linear accelerator, or Orthotron, and a 20-million electron volt Betatron have recently been installed.

FOUR-MILLION ELECTRON VOLT ORTHOTRON

The Orthotron at the Christie Hospital is one of a number which are to be installed by the National Health Service in different parts of the country. It was manufactured by Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester 17, and is illustrated in Fig. 1. It consists of a hollow metallic tube, or guide, 1 m. long, an arrangement which enables the adjustment mounting to be swung to the angle required for clinical treatment. Electrons are accelerated in this guice by an axial electric field and ride on a radio wave, the phase velocity of which is controlled by metallic discs, or irises, both wave and electrons travelling at the same speed.

A radial electric field and a circumferential magnetic field are also provided, the resultant effect of which is to disperse the electron beam. This dispersive effect is, however, compensated by a steady axial magnetic field, which is generated by solenoids surrounding the guide. To obtain the high electron energies necessary, fields of about 30 to 40 kV per centimetre are required in the wave guide. Very large radio power fluxes are therefore essential and pulse operations, similar to that used in radar equipment, must be employed. The source of radio frequency power is a 2-MW magnetron, which operates with a pulse of 2 microseconds duration and a recurrence rate up to 500 pulses per second. To increase the peak power flux in the accelerator guide to a value approximating 4 MW a system of feed-back is used. This is similar to the " back-to-back " test for motors, in which large circulating powers are obtained while the primary power source only supplies the losses.

X-RAY HEAD

The Orthotron is mounted so that it can be moved to any angle in a 135-deg. arc in the vertical plane and then centred at the normal treatment position for the patient. The axis of rotation coincides with the treatment point, which is 100 cm. from the target. As will be seen from the illustration, Fig. 1, the accelerator overhangs its support by 6 ft. so as to provide adequate room for setting-up the patient.

The beam is defined by adjustable diaphragms in the X-ray head, which is shown in Fig. 2. These diaphragms are supported on arms, which are hinged at the target and allow the size of the field to be adjusted. The edges of the diaphragms remain parallel to the edge of the X-ray beam, so that oblique absorption is reduced to a minimum. Moreover, the diaphragms extend more than half-way from the target to the skin, so that the penumbra is no wider than that of the focal spot, that is, about 5 mm. They can be adjusted to give field sizes from 4 by 4 cm. to 25 by 30 cm., with a limiting beam diameter of 31 cm., at 1 metre. When circular fields are required, insertions pierced by a conical hole are fixed in the jaws formed by the outer diaphragms.

CONTROL ARRANGEMENTS

All the controls, with the exception of those required for setting up the patient, are concentrated on a single desk, those used by the radiographer being mounted on a sloping panel and those employed by the technician to set up the equipment being contained in a well, which is normally covered by a sliding panel. Ionisation chambers in the X-ray head, in conjunction with electronic apparatus in the control desk, enable the equipment to be switched off automatically after a predetermined dose has been given. Alternatively, the dose can be terminated by an automatic timer or by hand. Meters indicate both the dose rate and the dose given.

To facilitate maintenance, the magnetron, which provides the radio-frequency power, can be replaced without disturbing the vacuum, while the electron gun is fitted with a turret carrying four filaments, so that a replacement can be effected in a few minutes.

The short pulses with which the equipment is energised last 2 microseconds and can be repeated at rates up to 500 per second. At this maximum rate an energy of 4-million electron volts can be maintained and an unfiltered output of 330 röntgens per minute produced at 1 metre from the X-ray target. A maximum output of about 200 röntgens per minute is obtainable after a filter has been inserted to provide a uniform beam over a wide area with the diaphragm fully open. As in practice treatment at a rate of 100 röntgens per minute is found to be convenient, the equipment is operated well within its capabilities.

BETATRON DESIGN

The Betatron, which was presented to the Christie Hospital by the Metropolitan-Vickers Electrical Company as a gesture of co-operation in exploring the use of super-voltage machines for clinical purposes, is shown during installation in Fig. 3. It consists essentially of an alternating-

Fig. 1 The 4-million electron volt Orthotron, which has been installed at the Christie Hospital, Manchester, showing the X-ray head in the vertical position.

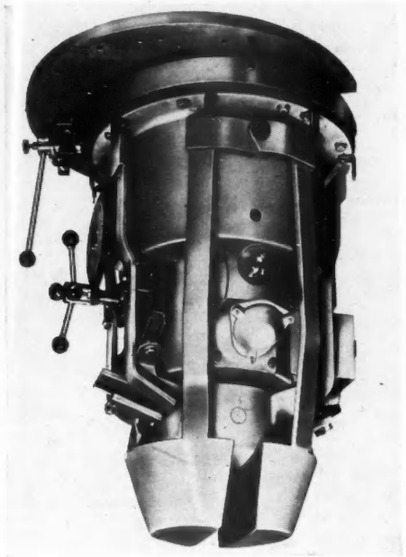


Fig. 2 X-ray head on the Orthotron.

current magnet the central limb of which has specially shaped pole pieces. This magnet weighs 7½ tons and can be rotated through 120 deg., so that the X-ray beam can be transmitted in any direction from 15 deg. above the horizontal to 15 deg. beyond the vertical. It is excited from a 150-cycle tripling transformer, which is fed from the three-phase mains. A continuously-evacuated glass toroid, or "doughnut," is inserted between the poles of the magnet. Electrons are injected into this toroid by a gun, which is pulsed at a voltage of 60,000 electron volts for 4 microseconds when the field between the poles is very small. A stream of electrons is thus circulated round the toroid in an orbit of 19 cm. radius, 80 electron volts of energy being added to it by magnetic induction during each revolution. A condition of maximum energy is reached in this way in $\frac{1}{600}$ second, and the orbit is then expanded, so that the electrons spiral outwards and make contact with a platinum target at the end of the gun. A relatively narrow cone of X-rays is thus produced in a forward direction and occurs as a series of 2 microsecond pulses 150 times per second. In order to reduce the power consumption, the magnet is connected in parallel with a 1,600-kVA condenser bank, so that it is only necessary to supply its losses, which amount to about 20 kW.

Radiation from this Betatron is applied to the patient through a collimator into which different treatment cones can be fitted according to the field shape required. Each of these cones contains a compensating filter, so that the beam intensity across the treatment area is uniform. The maximum size of the field that can be irradiated is 15 cm. in diameter at 1 m. from the target and the X-ray yield, before the insertion of the compensating filters, is 100 röntgens per minute at the same distance.

RESOMAX UNIT

The Orthotron and Betratron just described are supplemented for control purposes by a Resomax unit, which was manufactured by Newton Victor, Limited, 132 Long Acre, London, W.C.2. This consists essentially of a resonant coreless transformer within which a multi-section X-ray tube is coaxially mounted. The tube head assembly is oil-immersed, while the tube target, which is at earth potential, projects about 30 in. from the main tank. A clear field is thus provided for the X-ray beam and for quickly and conveniently setting up the patient. As the target is earthed it can be cooled by mains water.

The X-ray head itself is supported on a single pillar without projections, so that an unobstructed floor area is available for manœuvring the treatment table. It can be raised or lowered through 72 in. and turned through an angle of 370 deg. by motors, which are controlled by push buttons. Rotation in the vertical plane can be effected manually.

In addition to its use for therapeutic purposes the Betatron has found some application in nuclear research; both it and the Orthotron have also been employed for the radiography of heavy and thick objects. As the Orthotron has the useful properties that its electron beam is easily accessible and its current output is high it has been utilised in certain irradiation processes, such as the sterilisation of pharmaceutical products. Electron bombardment from it has also been shown to bring about desirable changes in the physical properties of certain plastics. For example, suitably irradiated polythene is insoluble and can no longer be melted.

* * *

LUBRICANT FOR DIAMOND WHEELS

For cleaning, lubricating and cooling diamond wheels, tools, and dies, Diamoil lubricant, manufactured by M. G. Beyerinck, Arnhem, Holland, is now distributed in the United Kingdom by the Oakland Metal Company, Limited, 142, New Bond-street, London, W.1. The use of Diamoil for cleaning and lubricating diamond wheels is said to result in a greatly improved surface finish of the tool being cut and a reduced grinding time.

Fig. 3 20-million electron volt Metropolitan-Vickers Betatron during installation at the Christie Hospital.

LAUNCHES AND TRIAL TRIPS

M.S. "HÖEGH SKEAN."—Single-screw oil tanker, built and engined by the Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for A/S Bisca and A/S Alliance (Managers: Leif Höegh & Co. A/S), Oslo, Norway. Eighth vessel built for these owners. Main dimensions: 526 ft. between perpendiculars by 69 ft. 9 in. by 39 ft. 3 in.; deadweight capacity, 18,100 tons on draught of 30 ft. 5 in.; oil-cargo capacity, about 870,000 cub. ft. B. and W. nine-cylinder two-stroke Diesel engine developing 9,000 b.h.p. Speed, 15¾ knots. Launch, October 21.

M.S. "VIKAREN."—Single-screw cargo vessel, with accommodation for twelve passengers, built and engined by the Götaverken Shipyard, Gothenburg, for the Rederiaktiebolaget Transatlantic, Gothenburg, Sweden. Main dimensions: 426 ft. overall by 57 ft. 6 in. by 35 ft. to shelter deck; deadweight capacity, about 7,050 tons on a draught of 23 ft. 2½ in. Götaverken seven-cylinder single-acting two-stroke Diesel engine, developing 3,900 b.h.p. at 120 r.p.m. Speed, 14½ knots, fully loaded. Delivered, October 22.

H.M.S. "LETTERSTON."—Twin-screw coastal minesweeper, built by Harland and Wolff, Ltd., Belfast, for the Admiralty, London, S.W.1. Main dimensions: 152 ft. by 28 ft. 9 in. by 14 ft. 9 in.; armament, three small guns. Diesel propelling machinery supplied by Mirrlees, Bickerton and Day Ltd., Stockport, Cheshire. Launch, October 26.

S.S. "JAMES ROWAN."—Single-screw self-trimming collier, built by Hall, Russell & Co., Ltd., Aberdeen, for the British Electricity Authority, London, S.W.1. (Managers; Stephenson Clarke Ltd., London, E.C.3.) Main dimensions: 323 ft. between perpendiculars by 43 ft. 3 in. by 25 ft. 9 in.; deadweight capacity, about 3,700 tons on a draught of 18 ft. Direct-acting triple-expansion steam engine of reheat design, developing 1,475 i.h.p. in service, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Steam supplied by two oil-fired cylindrical boilers. Launch, October 26.

M.S. "LONDON INTEGRITY."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for London and Overseas Freighters Ltd., London, W.1. Eighth vessel supplied to these owners. Main dimensions: 525 ft. between perpendiculars by 71 ft. by 39 ft. 3 in.; deadweight capacity, about 18,000 tons on a summer draught of 30 ft. 5⅜ in. N.E.M.-Doxford six-cylinder single-acting two-stroke opposed-piston oil engine, developing 6,800 b.h.p. at 119 r.p.m., constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Speed, 15 knots. Launch, October 28.

M.S. "HAVSÖY."—Single-screw oil tanker, built and engined by the Götaverken Shipyard, Gothenburg, Sweden, for Skibs A/S Truma, Arendal, Norway. Main dimensions: 550 ft. overall by 60 ft. by 39 ft. 3 in.; deadweight capacity, about 17,400 tons on a draught of 30 ft. 2 in. Götaverken nine-cylinder single-acting two-stroke Diesel engine, developing 6,750 b.h.p. at 112 r.p.m. Speed, about 15 knots, fully loaded. Launch, November 2.

S.S. "CERINTHUS."—Single screw oil tanker, built and engined by Harland and Wolff, Ltd., Belfast, for the Hadley Shipping Co. Ltd., London, E.C.3. Main dimensions: 530 ft. between perpendiculars by 69 ft. 3 in. by 39 ft. to upper deck; deadweight capacity, 18,000 tons. Double-reduction geared steam turbines, developing 7,500 s.h.p. in service. Steam supplied by two Babcock and Wilcox oil-burning water-tube boilers. Trial trip, November 8.

M.S. "CHRISTINA PEZAS."—Single-screw cargo vessel, built by Short Brothers, Ltd., Sunderland, for A.K. Pezas & Transolas Compagnia Naviera S.A., Panama. Main dimensions: 438 ft. 2 in. between perpendiculars by 59 ft. 9 in. by 38 ft. 2 in. to shelter deck; deadweight capacity, about 10,000 tons on a mean summer draught of 26 ft. 2½ in. Six-cylinder single-acting two-stroke opposed-piston Diesel engine, developing 4,400 b.h.p. at 115 r.p.m., constructed by Harland and Wolff, Ltd., Belfast, and installed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Launch, November 10.

M.S. "SCOTTISH HAWK."—Single-screw oil tanker, built by the Greenock Dockyard Co., Ltd., Greenock, for the Scottish Tanker Co., Ltd. (Managers: Cayzer, Irvine & Co., Ltd.), London, E.C.3. Main dimensions: 543 ft. 3 in. overall by 69 ft. by 38 ft. 6 in.; deadweight capacity, about 16,400 tons on a mean draught of 29 ft. 10 in.; gross tonnage, 11,250. Wallsend-Doxford six-cylinder heavy-oil engine, developing 6,400 b.h.p. at 115 r.p.m. in service, constructed by the Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne. Launch, November 11.

TELEVISION TRANSMITTING STATION IN THE ISLE OF WIGHT

FIRST OF FIVE MEDIUM-POWER TRANSMITTERS NOW IN SERVICE

To improve the reception of television in certain parts of the country in which the service has hitherto been unreliable, the British Broadcasting Corporation is constructing five medium-power transmitters, the first of which, at Rowridge, in the Isle of Wight, was put into regular service on Friday, November 12. The station has been built on a site 26 acres in area, at a height of 470 ft. above sea level, situated 3½ miles west-south-west of Newport, and will eventually serve an area of some 40 or 50 miles radius which includes the whole of Hampshire, parts of Dorset, Wiltshire and West Sussex, as well, of course, as the Isle of Wight. At present, however, its range is some 10 to 20 miles less, owing to the fact that a temporary mast and aerial system is in use, but it is hoped that the permanent mast and aerial will be completed by the autumn of next year.

SITE AND BUILDING

The station is reached by an approach road 1¼ miles in length and as it is about three miles from the nearest water main, the water required has to be brought to the site in tankers. These deliver it into an underground tank, of 2,000 gallons capacity, from which it is pumped into two high-level tanks in the building by automatic electrically-driven pumps controlled by float switches. Electric power is taken from the 11-kV network of the Southern Electricity Board and is transformed on the site to three-phase 50-cycle current at 415 volts, by means of a 200-kVA delta-star connected transformer. Supplies for the transmitters and the programme-input equipment are obtained through regulators which keep the voltage constant to within ± 1 per cent. irrespective of normal fluctuations in the incoming supply. A 32-kVA Diesel engine-driven alternator, generating single-phase 50-cycle current at 240 volts, is installed for use as a stand-by and starts up automatically in the event of failure of the main supply. The set is of sufficient capacity to provide power for the vision and sound input equipment, the low-power stand-by vision and sound transmitters and the essential lighting. It was constructed by Dale Electric (Yorkshire) Limited, Filey, Yorkshire.

TRANSMITTERS

The building is of brick construction with a flat concrete roof supported on pre-cast concrete beams. The floors are also mainly of concrete with numerous ducts for cables and pipes. The main vision transmitter, which operates on a frequency of 56·75 megacycles per second, was constructed by Marconi's Wireless Telegraph Company, Limited, Chelmsford, and has a peak white output of 5 kW. Modulation is carried out at the 500-watt level, the signals then being amplified by two radio-frequency amplifiers each using a pair of triodes, with forced-air cooling, made by the English Electric Company, Limited. The filaments of the transmitter valves are heated by alternating current, while those of the amplifiers are supplied from metal rectifiers. High-tension current is obtained from hot-cathode mercury-vapour rectifiers which supply a maximum of 3,000 volts for the amplifier stages. The sound transmitter, also constructed by Marconi's Wireless Telegraph Company, Limited, operates on a frequency of 53·25 megacycles per second, and has a rated output of 2 kW, but the output is adjusted to 1·25 kW in order to maintain the standard power ratio of 4 to 1 between vision and sound. All valve filaments are heated by alternating current and, as is also the case with the vision transmitter, the crystal-controlled drive and the power-conversion equipment are built as an integral part of the transmitter.

CONTROL ARRANGEMENTS

Both transmitters are contained in similar sheet-steel cubicles which are mounted side by side to present a single continuous front in the transmitter hall, as shown in Fig. 1. The air-blast cooling equipment and combining filter are mounted behind the transmitter cubicles which are built into a soundproof partition wall in order to isolate the noise of the blowers from the control desk situated in front of the transmitters, as shown in Fig. 1. The two transmitters are controlled and monitored from this desk which incorporates, in addition to the conventional controls and meters, a built-in waveform monitor and two picture monitors which enable the incoming picture to be compared with that radiated. The controls of each transmitter are sequence-interlocked to ensure that they are used in the correct order and with the appropriate time interval between the various supplies where necessary. Test waveform-generating equipment is provided near the control desk for producing a variety of signals required for testing, lining-up and maintaining the characteristics and performance of the vision transmitter. Low-power stand-by transmitters, manufactured by Standard Telephones and Cables, Limited, will shortly be installed, and operated on the same frequencies as the main transmitters, with outputs of 500 watts and 125 watts for vision and sound, respectively.

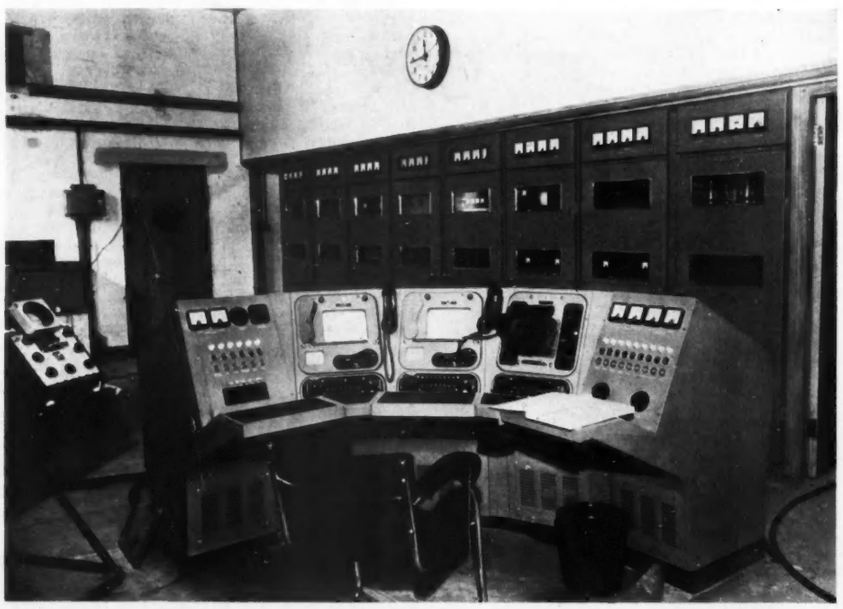


Fig. 1 Transmitter hall, showing control desk with main vision and sound transmitters behind it.

Fig. 2 200-ft. temporary mast supporting the main and reserve transmitting aerials for vision and sound. At the extreme top is an aerial for receiving the programme from Wenvoe in emergency; and nearer the base is the reflector for the P.O. microwave link by which the vision programme is received from Alton in Hampshire.

SUPPLY OF PROGRAMME MATERIAL

The vision programme radiated from Rowridge is derived from Alexandra Palace, London, and is supplied through a Post Office repeater station at Alton in Hampshire. From Alton, the vision signal is re-radiated by a microwave-link transmitter and is received at Rowridge by Post Office equipment from which it is passed to the B.B.C. vision-input equipment and thence to the transmitter. Ultimately, two microwave links will be available, one normally acting as a spare to the other, and they will be reversible so that outside broadcasts from the Isle of Wight can be relayed to the mainland for connection to the main television network. The sound programme is supplied to Rowridge through special P.O. telephone circuits which include a submarine cable between Southampton and the Island.

TEMPORARY AND PERMANENT AERIALS

The receiving reflector for the microwave link between Alton and Rowridge is mounted at the 60-ft. level on the temporary 200-ft. self-supporting mast, illustrated in Fig. 2, which also carries two dipoles forming a simple two-stack

array for the transmission of sound and vision. They are mounted at the 175-ft. level, while, at the top of the tower, aerials have been provided for receiving the television programmes radiated from the high-power transmitter at Wenvoe in the event of a breakdown in the normal programme route. The permanent mast, which will be 500 ft. in height, will carry an aerial system of greater vertical directivity and the combination of height-gain and increased effective radiated power will provide greater field-strength and additional coverage. The final results will be of great interest to viewers in the area affected, as well as to those responsible for the design and construction of the station, but doubtless many of the former will have already experienced materially improved reception.

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HIGH FREQUENCY ALTERNATOR

Self-contained Pattern with Permanent-Magnet Excitation

A high-frequency self-contained alternator in which the excitation is provided by a permanent magnet, instead of by a direct-current field winding supplied from an external source, has recently been developed by the British Thomson-Houston Company, Limited, Rugby. It has a continuous output rating of 250 volt-amperes at 115 volts and 1,600 cycles when running at 2,400 r.p.m. It is totally enclosed, water-tight up to the shaft level, and fully shockproof.

The general construction of the alternator is shown in the accompanying illustrations. It is a homopolar inductor machine with an annular magnet of " Alcomax III " incorporated in the rotor, the shaft of which is non-magnetic steel. A magnetising coil is wound over the magnet and its ends are brought out to terminals mounted on the rotor end-flange. During manufacture, a current of about 100 amperes is passed momentarily through this coil to magnetise the rotor in an axial direction.

An important feature of the design is that the rotor can be removed from and replaced in the stator without loss of magnetism, although if the rotor itself is dismantled, it is necessary to re-magnetise it after re-assembly. This can, however, be done quite easily by using the coil provided, without the need for any special jig.

Tests show that the rotor magnetism is not affected by such drastic treatment as, for instance, short-circuiting the output winding through a series capacitor, which resonates with the winding inductance at the operating frequency.

Provision is made for sufficient voltage adjustment to cover variations in manufacture and materials by varying the angle of offset between the teeth of the two rotor cores. As usual with high-frequency alternators, a capacitor is connected in series with the alternator winding to improve the load regulation characteristic. With such an arrangement, the regulation from full rated load to open circuit may be as low as 20 per cent.

The new machine was initially designed for use as the pilot exciter of a turbo-alternator set with " Magnestat " automatic voltage regulation, the permanent magnet alternator providing the magnetic amplifier with a conveniently high-frequency supply to allow the size of the former to be reduced and a high speed of response to be obtained. It can, however, be employed where close voltage regulation is unnecessary or where the load only varies over a small range. In such cases, it is claimed, it has advantages over direct-current excitation.

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7-TON MOBILE CRANE

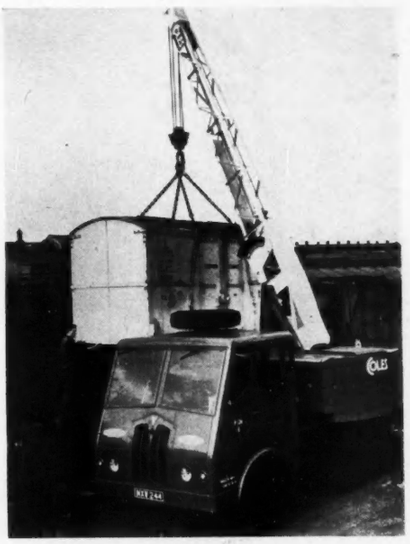
Power from Diesel-Generator Set

The mobile crane shown in the two accompanying illustrations has been developed specifically by the manufacturers, working in conjunction with railway engineers, for use in railway goods yards. To be known as the Coles " Leander " and made by Steels Engineering Products, Limited, Crown Works, Sunderland, the crane is lorry mounted and the motions of hoisting luffing, slew and travel are controlled from the one chassis cab. As can be seen from the smaller illustration the driver's seat can be swivelled through 180 deg. from the normal driving position to face the crane-operating position. The controls are of the simplest kind, there being one lever for each motion, but a duplicated travel controller has been provided so that manœuvring is quite feasible when the driver is facing rearwards to the crane. The cab is totally enclosed, although opening windows fitted with safety glass give all-round vision.

The Leander has a load capacity of 7 tons at 10 ft. 6 in. radius when using a standard 20-ft. jib.; the jib is of lattice construction and is available in different lengths from 20 ft. up to 40 ft. by increments of 5 ft. Power for the crane motions is obtained from a Diesel engine mounted on the chassis and directly coupled to a variable-voltage generator, which supplies current to three separate motors for hoisting, luffing and slewing.

The usual safety devices have been embodied in the design, including an automatic safe-load indicator which, irrespective of the jib position, cuts out the motor to prevent an unsafe load from being lifted; self-resetting limit switches to protect the machine and load should attempts be made to hoist or luff beyond the prescribed limits; electro-mechanical brakes to the hoist and luffing motions, these being applied instantaneously should the current supply be interrupted either accidentally or intentionally.

The chassis is a six-wheeled Coles crane-carrier with twin wheels at the rear. Foot-operated hydraulic brakes have been fitted to all wheels, but the handbrake, of the multiple-pull ratchet type, operates on the rear wheels only. A two-speed gearbox makes the crane suitable for normal roadwork, and conventional lighting, horn and instrument panel are fitted as standard equipment.



With a 7-ton lift at 10 ft. 6 in. radius, the new Coles mobile crane was designed specifically for work in railway goods yards.

For easier control of the crane motions, the driver's seat can be swivelled to face the revolving superstructure. A duplicated travel controller allows the driver to manœuvre the crane while facing the rear.

★ ★ ★

COUPLING ALIGNMENT CALCULATOR

A calculating device which is claimed to reduce the time taken in aligning shafts to be coupled has been developed at the Heysham Works of Imperial Chemical Industries, Limited. Two dial gauges are first clamped on the coupling, one on each half, and at 180 deg. to each other. From their readings the thickness of shims required under the feet of the motor can be calculated using the device described.

Basically, the calculator consists of four parallel scales, suitably divided, and a straight-line cross cursor. The scales are set at distances corresponding to the positions of the gauges and the feet to be shimmed and the cursor adjusted to half the gauge readings on the corresponding " gauge " scales. The resulting readings on the " feet " scales give the shim thicknesses required to align the shafts correctly.

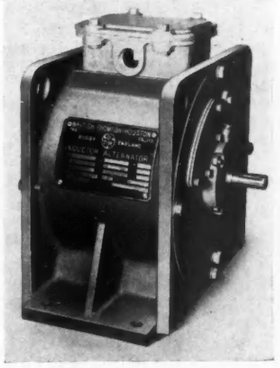


Fig. 1 High-frequency alternator with permanent-magnet excitation.

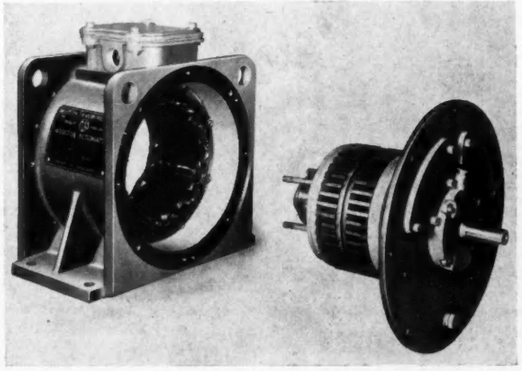
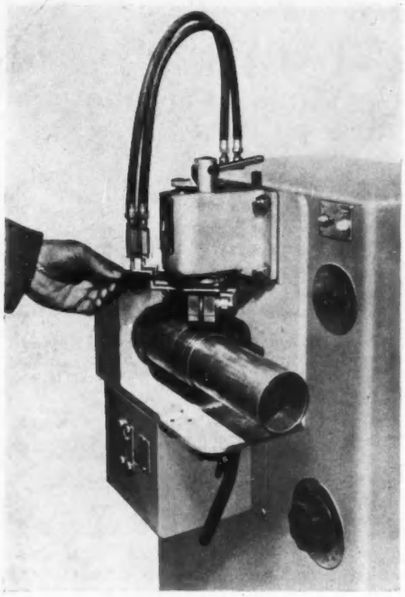


Fig. 2 The rotor removed from the stator. The machine has an output of 250 volt-amperes at 1,600 cycles.



Two lengths of thin-walled tube, one fitting in the other, are rotated slowly while a circumferential row of spot welds is completed.

WELDING THIN-WALLED TUBES TOGETHER

Automatic Machine for Spot Welding

A machine for seam-welding metal tubes and bellows having wall thicknesses of only a few thousandths of an inch is now being produced by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. This machine has been developed from the 4-kVA electronically-controlled spot welder used on mass production lines for joining very thin metal components.

The new machine is a precision instrument designed for use by an unskilled operator. All the operator has to do is to place the overlapping lengths of tube on a chromium-copper mandrel forming the lower electrode, move two levers, one bringing the upper electrode disc into the working position, the other bringing into use a smoothing roller, and switch on.

The mandrel is rotated at a fixed speed of one revolution a minute by a geared fractional-horse-power motor, and the welder is brought into operation by a rotary switch with three positions marked "off," "run" and "weld." The use of a single switch ensures that switching is carried out in the correct sequence, the motor being started before welding is begun and switched off only after welding has been stopped.

With the switch in the "weld" position a series of spot welds is carried out automatically. The welds are of one-cycle ($\frac{1}{50}$ sec.) duration, accurately timed by an electronic circuit, and can be spaced 2, 3, or 4 cycles apart. A tube assembly with an overall diameter of 3½ in. would be welded by this machine at a speed of 11 inches a minute and have 91, 68, or 55 spot welds per inch, according to the setting.

A tube assembly is clamped firmly in position on the mandrel by means of a ring-section spring, loaded radially downwards to pull the parts tightly into contact with the mandrel surface where welding takes place. The radial displacement of the ring is always downwards although the mandrel rotates. The ring (which is the subject of a patent application) can be centred to allow tubes to be placed in position.

The upper electrode assembly, which is water cooled, is mounted eccentrically so that it can be moved easily and quickly into alternative working positions to produce two seams spaced ¼ in. apart. This movement is shown in the illustration.

The machine will seam weld together two stainless-steel tubes each with a wall thickness of the order of 0·015 in., Inconel or nickel tubes each with a wall thickness of about 0·009 in., and brass or copper with wall thicknesses of about 0·005 in. Tube assemblies having diameters up to 6 in. can be handled, using different mandrels.

Graduated scales fitted to the machine enable recordings to be made of current and pressure settings, the latter being variable between 25 and 150 lb. per square inch. The welder is arranged to operate from a 400/440-volt, 50-cycle, single-phase supply.

* * *

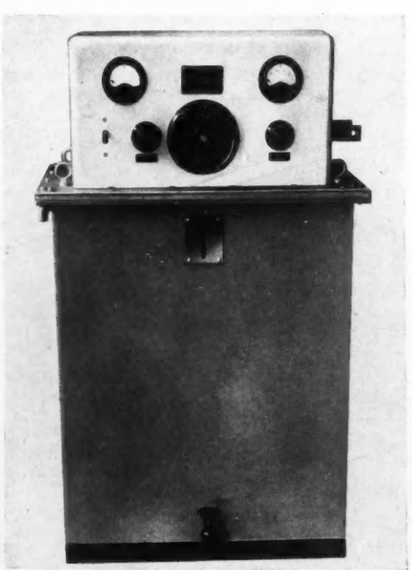
RECTIFIER EQUIPMENT FOR PLATING AND ANODISING

Single-Vat Units

In order to take advantage of the operating economies that can be effected by using separate supplies for each plating vat, the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, have introduced a series of rectifier units. These comprise three main components mounted together: a variable auto-transformer, a double wound transformer and a full-wave bridge-connected selenium rectifier. The model shown in the illustration below will supply 300 amperes at 6 volts.

The mains input supply is fed through a switch and fuse to the variable auto-transformer which is used for controlling the output voltage. The variation provided by this means is continuous from zero to the maximum rated output of the rectifier unit. The output from this auto-transformer is applied to the double-wound transformer, where it is stepped down to the necessary value to supply the rectifiers. The direct-current output is monitored by a moving-coil voltmeter and ammeter, both of which are protected against corrosive fumes.

To eliminate the problems of cooling and corrosion, both transformer and rectifier are oil-immersed, using clear oil. A thermostat, located near the surface of the oil, sounds a warning bell and switches on a red pilot light if the temperature rises beyond a safe limit. The pilot light, bell and Variac control together with the meters are housed in a drip-proof compartment above the tank. Cooling is provided by natural convection, the warm oil rising up the centre and moving towards the sides of the tank, which are cooled by the surrounding air. In extremely large tanks this movement can be increased by providing vertical tubes down the sides of the tank which increase the area in contact with the outside air.



By using unit rectifiers such as this, economies can be effected in the operation of plating equipment.

To minimise the difficulties caused by accidental short circuiting when the vats are being loaded, the output current is limited to not more than 300 per cent. of the full-load current, and the rectifiers will withstand this overload for a period of several minutes.

Normally, rectifiers are supplied for single-phase working, but for large units three-phase working is preferable, because it enables a smoother output and higher efficiency to be obtained. For special purposes, such as chromium plating, three-phase units can be supplied in which the ripple of the output is less than 4 per cent. The smaller units are housed in one case, but in the case of the larger units, transformer, rectifier and control gear are housed in separate units.

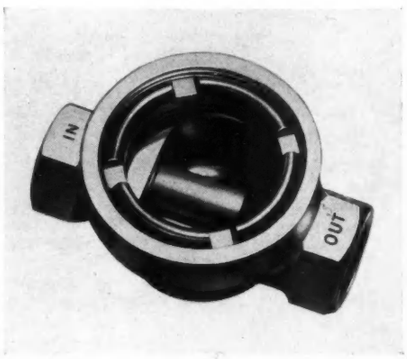
The units described are designed for operation in an average ambient temperature not exceeding 35 deg. C. (95 deg. F.). When required for use in tropical climates the ratings of the rectifier sets are reduced and the ambient temperature correspondingly increased. Tropically rated sets so modified are claimed to be suitable for operation in an ambient temperature of 55 deg. C. (131 deg. F.).

* * *

SIGHT GLASS FOR STEAM TRAPS

Glass Erosion Eliminated

In the accompanying illustration is shown the latest design of sight glass manufactured by Spirax-Sarco, Limited, Cheltenham. The method of directing flow across the viewing space is unusual in that a totally-enclosed channel extends the greater part of the distance across the glassed-in space.



In this sight glass, the flow is directed through a totally-enclosed channel extending the greater part of the distance across the closed-in space. Erosion of the glass window by a jet of water is thus eliminated and, owing to the ejector effect, the glass is virtually self-cleaning.

The principal virtue claimed for the design is that, while offering a visual check on flow, it aims to eliminate the problem of glass erosion which is often present when a jet of water impinges on the underside of the window of a sight glass.

The "ejector" effect of the arrangement illustrated makes this new pattern of sight glass virtually self-cleaning. The first size to be made has ½-in. connections.

THE PUBLIC WORKS CONGRESS AND EXHIBITION

Concluded from page 667

We conclude below our descriptions of some of the machinery and equipment that was displayed at Olympia during the week that the Public Works Congress and Exhibition was open. The Exhibition is the subject of editorial comment in Weekly Survey.

GAS-TURBINE ALTERNATOR SET

An item which was completed only as the Exhibition opened was the gas-turbine alternator set on the stand of Petbow Limited, Sandwich, Kent. Hitherto, Diesel-driven generator sets have predominated on civil-engineering sites and in the Armed Services, etc., for the local and temporary generation of electrical power, and the development of the gas turbine for producing electricity has been confined to large stationary sets for installation in power stations. But on display was what is thought to be the first portable turbo-alternator set; it is illustrated in Fig. 13.

The set is built from two units: the Rover gas turbine which has a continuous rating of 60 h.p. for a weight of 120 lb., and was described in ENGINEERING, page 507 of the issue of April 16 last; and an alternator developed specially for this set by the Macfarlane Engineering Company, Glasgow, and Petbow. The new set generates 50 kVA at 440 volts on a three-phase supply. Fully equipped within the tubular frame the unit weighs less than 1,000 lb., whereas a Diesel generator set of orthodox design would weigh perhaps five or six times that figure. Apart from its lightness, the set also has the advantages of freedom from vibration and that maintenance can be undertaken by relatively unskilled labour. Details of performance are not yet available.

MOBILE CRANE

The latest developments in the range of mobile cranes built by R. H. Neal and Company, Limited, Ealing, London, W.5, were illustrated by a small selection of machines, including that shown in Fig. 14, herewith, a standard "QM" machine, but fitted with the flying jib.

The main base jib, of lattice-work construction, is 45 ft. long but the addition of the 12-ft. long flying jib greatly increases the handling efficiency of the crane at higher levels as, for example, on constructional work. When the crane is fitted with two hoist drums—and provision can be made for this in all the QM cranes—the line for the base jib runs from the main hoist drum, the second drum then carrying another line, through separate sheaves, for the flying jib. In this way the base jib can be used for all normal handling of heavy loads without employing the flying jib. Alternatively, a single line to the flying jib may be used as on cranes with only a single hoist drum. Typical load-capacity figures are (using the flying jib): 1 ton at 25 ft. radius to a height of 51 ft. 3 in.; ½ ton at 34 ft. radius to 46 ft. 3 in. The exhibited model is mounted, as illustrated, on pneumatic tyres, but crawler tracks can also be fitted.

Another exhibit was the Neal lorry loader, which was shown fitted to a Dennis long wheelbase lorry; this unit has a capacity of up to 1½ tons and was described in ENGINEERING, vol. 176, page 652 (1953).

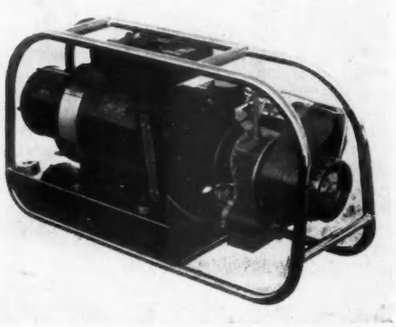


Fig. 13 Portable 50-kVA Petbow turbo-alternator set driven by the Rover 60-h.p. gas turbine.

HYDRAULIC-CONTROL UNITS

For their first appearance at the Exhibition, Keelavite Rotary Pumps and Motors, Limited, Allersley, Coventry, have been showing a selection from their range of 1,500 standard units used in the hydraulic transmission of power. Typical applications are the control of gas-distribution valves, gate valves, storm and flood valves, lock gates as well as of machinery including earth-moving equipment. A working exhibit, staged in conjunction with Robert Cort and Son, Limited, Reading, illustrated the operation and remote control of a town's rotary gas valve by the company's hydraulic units.

The company has recently developed a range of fixed-capacity pump/motor units with displacements up to 50 cub. in. per revolution for the transmission of power at rates ranging from fractional horse-power up to 250 h.p. at 2,000 lb. per square inch; some of these units were shown on the stand. The complete range emanates from six basic designs, each unit functioning either as a pump or motor in either direction of rotation without any modification in assembly.

Among the pressure and flow-control equipment were two new items, a series of ¼-in. pilot-operated solenoid valves and a re-designed flow-dividing valve. The pilot valves are suitable for either single- or double-solenoid operation (one, without its casing, is shown in Fig. 15) and can be attached directly to Keelavite directional valves to form a composite pilot-operated directional control unit or, with an alternative baseplate, can be fitted in a pipe line to perform normal piloting duties. The terminal box can be rotated through 360 deg.

WATER TREATMENT

Plant and instruments designed for the application of chemicals in the domestic and industrial fields are on display on the stand of Wallace and Tiernan, Limited, Power-road, London, W.4.

Foremost on the stand was the newly-developed WT Silacator which has been specially designed for the accurate production and feeding of chlorine-activated silica. (The use of such silicas is now well established as an invaluable aid to coagulation and sedimentation for the purpose of removing particular matter from turbid raw waters.) The advantages of the Silacator are its continuous action in the process of silica activication; handling of the chemicals is largely eliminated, these being used directly from the suppliers' containers; it is compact, requiring little floor space and no major structural work for its support.

Another prominent feature among the exhibits was a typical layout of automatic de-chlorination and control of the residual chlorine, so important in the treatment of water supplies; the apparatus displayed is capable of both measuring the chlorine residual and relaying the measurement back to the controlling apparatus so that complete regulation is maintained over the residual. Other forms of chemical-control apparatus and chemical-feed devices for a wide range of processes and conditions were also exhibited.

20-CUB. YD. SCRAPER

Among the stands devoted to really large earth-moving equipment was that sponsored by the four United Kingdom agents for "Caterpillar" and Hyster industrial equipment. The largest unit on the stand was a 15- to 20-cub. yd. pneumatically-tyred scraper, built under licence by the Birtley Company, Limited, Birtley, and displayed behind a D8 "Caterpillar" tractor. A similar scraper, but behind a 225-h.p. DW21 tractor, is shown in Fig. 16, on page 706; the photograph was taken at Spade Mill reservoir site, Longridge, near Preston, Lancashire, where a number of these scrapers are being used to excavate several million cubic yards of clay for the new reservoir.

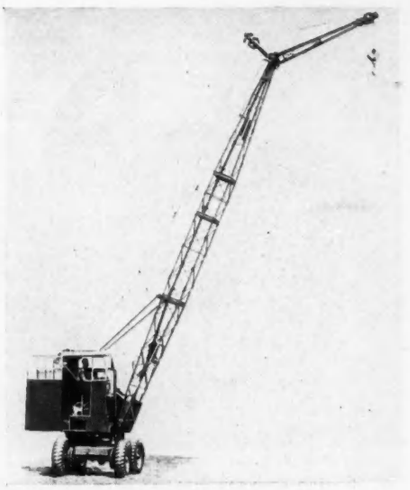


Fig. 14 Standard Neal "QM" crane fitted with 12-ft. flying jib.

These scrapers, with a flat double-bottom bowl, have a struck capacity of 15 cub. yd. and heaped capacity of 20 cub. yd.; by adding extension boards and, where conditions permit, the carrying capacity can be increased up to 23 cub. yd. of loose material—the limiting load being 25 tons. The scrapers are cable operated, using a No. 27 cable-control unit, and brakes have been fitted to all four wheels. The width of the cutting edge is 9 ft. 6 in., and of the apron opening, 6 ft. 3 in.; ejection is forward and positive with a maximum depth of spread of 15¾ in. The original design and specification of the "Caterpillar" models has been closely adhered to so that the British-made machines are directly interchangeable with those made in America.

Other equipment on the stand included the new No. 6 shovel; this machine has bucket capacity of 1·5 cub. yd. struck, and 2 cub. yd. heaped, with a bucket width of 8 ft., and has an improved bucket mounted on a Caterpillar No. 6 crawler tractor. The lifting mechanism is entirely hydraulic to give a maximum digging depth of 14 in. below the ground line and a top dumping height of 10 ft. 9 in. The tractor is driven by a six-cylinder Diesel engine, water-cooled, developing its maximum torque at 900 r.p.m.; starting is by an independent two-cylinder petrol engine of 15 h.p., which is itself started by a six-volt battery-motor unit

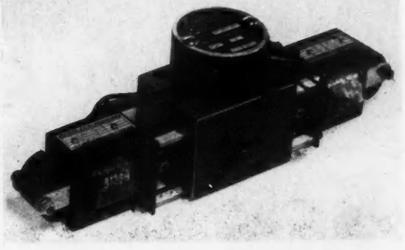


Fig. 15 Double-action Keelavite ¼-in. pilot valve actuated by two solenoids.

Fig. 16 The economical extent of mass excavation is being increased by the use of larger machines such as the Birtley "Caterpillar" 15 to 20 cub. yd. scraper.

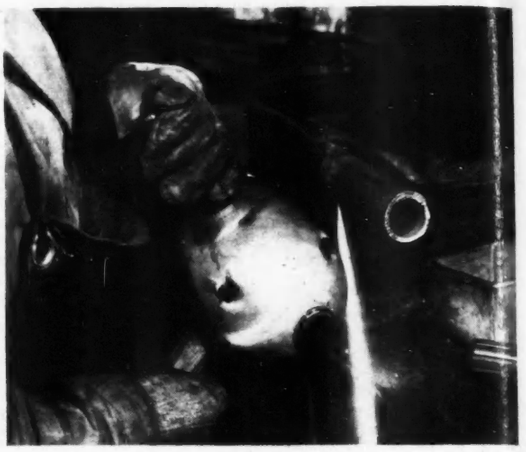


Fig. 17 Developed for using thin reinforced grinding wheels, the new Atlas grinder has a speed of 6,000 r.p.m.

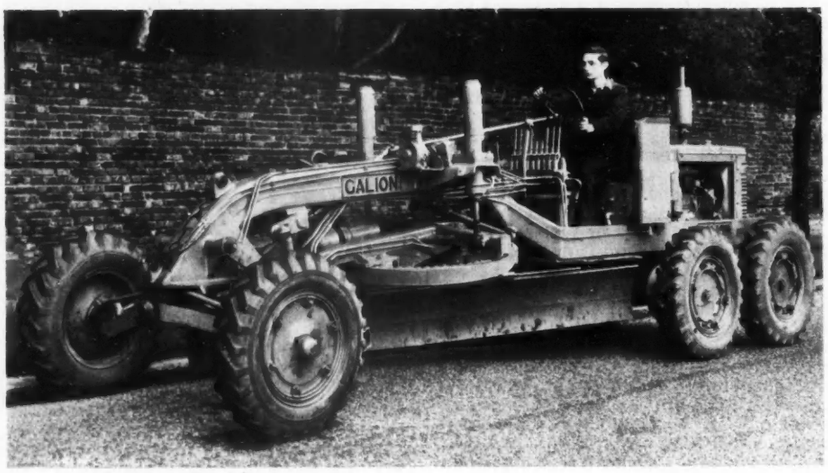


Fig. 18 The new British-made Galion "603" motor-grader has a hydraulically-controlled mouldboard 10 ft. long with a 45-in. reach outside the front wheels.

Fig. 19 The "Steelmaster" has a load capacity of 22,000 lb. and a road speed of 25 m.p.h.

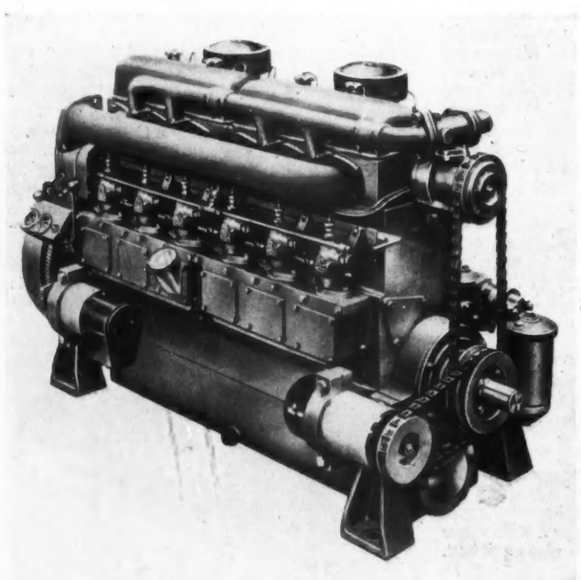


Fig. 20 Two-, three-, four- and six-cylinder versions, developing 12 b.h.p. per cylinder at 1,500 r.p.m., are included in the new Ruston and Hornsby Diesel engines.

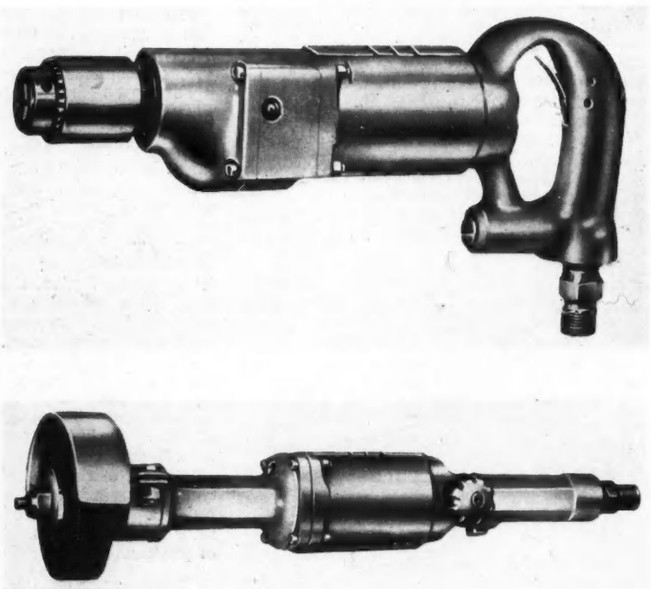


Fig. 21 Among the many compressed-air tools on the stand of Holman Bros. were the "Rotodrill" and "Rotogrind" both built round a small-size cartridge-type air motor.

controlled from the driver's seat. Overall dimensions of the machine are: length, 17 ft. 1 in.; width, 8 ft.; and height, 6 ft. 11 in. The maximum drawbar pull is 18,700 lb.

PNEUMATIC GRINDING HEAD

Among the many pneumatic tools exhibited by the Atlas Diesel Company, Limited, Wembley, most of which are new models, was a grinder which has been developed particularly for using thin reinforced grinding wheels. Known as the LSS-81, it develops 2½-h.p. at 6,000 r.p.m. when using a 9-in. wheel and can be used for notching and cutting risers from castings as well as for general finishing work. In Fig. 17, opposite, it is shown cutting off a length of thick-wall steel pipe. The weight is 11 lb. and several models are available to take different types of wheels or brushes.

Also included on the stand was a range of riveting hammers which will close any size of rivet up to ⅝ in. in diameter. Some models have long strokes, up to 6½ in., and have a blow-frequency adjustment which can be set to suit the class of work in hand. They are quite suitable for use with the high shear rivets recently introduced by Brown Brothers (Aircraft), Limited. Other tools exhibited were a valve grinder, chipping hammers, low- and high-speed drills, impact wrenches and hoists, these being in addition to the portable compressor mentioned last week.

MOTOR GRADER

Two motor graders were being exhibited by Galion (Great Britain), Limited, Wakefield, Yorks: the large 100-h.p. grader, model 118, which has been on the market for some years now, and a smaller machine, the 603, claimed to be the first British-built motor grader of its capacity. It is shown in Fig. 18.

Driven by a 50-h.p. International Harvester Diesel engine, the " 603 " is 19 ft. 6 in. long and has an overall width of 6 ft. 2 in. The mouldboard is 10 ft. long by 16⅜ deep, with a 12-in. lift above the ground; the maximum blade load is 5,470 lb. and the maximum side reach 45 in. outside the front wheels. The blade may be turned through 126 deg., all the blade movements being hydraulically controlled. A chain-driven tandem drive has been employed to all four rear wheels which, with the front wheels, are all fitted with the same size tyres. Four forward speeds are available, ranging from 2 to 12 m.p.h. in first gear up to between 18 and 20 m.p.h. in top gear; the single reverse gear gives a road speed of 3 m.p.h.

Additional equipment available for this machine as extras will be: a hydraulically-operated scarifier; an all-steel cab with safety-glass windows; leaning front wheels; a 12-ft. mouldboard; a snowplough; bull-dozer blades; as well as lights and other accessories.

Besides being shown on the stands of Galion, Limited, both the " 118 " and the " 603 " were among the machines on the two stands occupied by Jack Olding and Company, Limited, Hatfield, Herts. The principal equipment on these stands were the Vickers-Armstrongs VR180 tractor, driven by the supercharged six-cylinder Rolls-Royce oil engine, and its matched ancillary equipment: 'dozer blades, towing winch, rear-mounted cable-control units, and the Onions' 11-15 and 12-16 open-bowl scrapers and ripper. In addition to these two scrapers, new models of the same pattern—one larger, one smaller—are now available. The smaller model, the 3-4 scraper, has just been approved by the Ford Motor Company for use with the Fordson Major tractor, Mark III.

STRADDLE CARRIER

On the stand of Thos. W. Ward, Limited, Albion Works, Sheffield, was a new tower crane originally of French design. At the exhibition the crane had to be restricted in height to 62 ft., but the use of extension members will increase this to 101 ft. 6 in. At the maximum radius of 52 ft. 6 in. the crane will lift 1,760 lb. and 4,400 lb. at 23 ft. radius. The hoisting speed is 164 ft. per minute in high gear and 52 ft. 6 in. in low; slewing speed is 1 r.p.m. Driven by either a 20-h.p. Diesel engine or a 17-h.p. electric motor the crane operates along a 7 ft. 6 in. track.

Also on this stand is what is believed to be the only straddle carrier built in the Sterling area. Marketed by both Ward's and the British Straddle Carrier Company, Limited, 7 Chesterfield-gardens, Curzon-street, London, W.1, the machine is made in two forms: the " Steelmaster " for the conveyance of pipes, girders, machinery, etc., and illustrated on page 706; or, alternatively, as the " Timberwolf " for dealing with loads of timber. It is available with eight variations of load aperture to deal with loads of up to 40 ft. in length and of 7 to 8 tons in weight. The power unit is a 65-h.p. Perkins P.6 Diesel engine which gives the carrier a road speed of between 25 and 30 m.p.h., both forward and in reverse; all power transmission is by chain drives in totally-enclosed oil baths. From his elevated position the driver has a good view both fore and aft, with a good sight of the load throughout the operation of approaching, lifting and then setting down the load. The mechanical lifting gear is controlled by a single lever and the load can be raised or lowered, if need be, while the carrier is in motion.

The machine has a front-wheel drive and rear-wheel steering, which gives it a 9-ft. turning radius and easy manœuvrability in confined quarters. In a recent test, the carrier—with only one operator—was able to pick up a load of 7½ tons of steel or timber of about 23 ft. in length, convey the load over a distance of 220 yd., release the load and return to the starting point in under 80 seconds. On this basis, one machine can move more than 300 tons per hour over this distance.

As an addition it is intended to fix, in the near future, the Neal lorry-loader (which has already been mentioned on page 705) to the side of the vehicle, so materially extending its versatility.

NEW SERIES OF DIESEL ENGINES

Among the new series of Diesel engines being displayed at the Exhibition was that introduced by Ruston and Hornsby, Limited, Lincoln. Designated as series YC, the engine is available in units of two, three, four and six cylinders, with a maximum output of 12 brake horse-power per cylinder at 1,500 r.p.m. The cylinder dimensions are 4·375 in. diameter by 5 in. stroke. The six-cylinder model is illustrated in Fig. 20.

The engine is a four-stroke compression-ignition engine with an open-type combustion chamber, direct injection and water cooling. The crankcase and cylinder block are of " monobloc " construction with inspection doors giving access to connecting rods and big-end bearings. A steel stamping, hardened and ground, has been used for the crankshaft which is supported in steel-backed main bearings lined with a copper-lead alloy; the connecting rods are steel stampings of H-section and are removed by withdrawing them through the cylinder.

The pistons are of low-expansion silicon-aluminium alloy with three pressure rings and two scraper rings. The overhead valves, their operating gear and the injectors, are mounted in the cast-iron cylinder head; the Meehanite camshaft, gear driven from the crankshaft at the flywheel end of the engine, actuates the valves through push rods and rocking levers.

Each cylinder has an associated fuel pump which is of the helix single-unit pattern operated through rocker levers working off the camshaft which also drives the submerged gear pump for the lubrication system. For starting, a 24-volt system has been fitted on the six-cylinder engine, but hand starting with assistance from decompressor gear will be standard on the smaller models though 12-volt equipment can be supplied as an extra.

COMPRESSED-AIR TOOLS

The exhibits on the stand of Holman Bros., Limited, Camborne, were all related to the use of compressed air, either as various sizes and types of compressor or as pneumatic tools. The smallest stationary set on the stand is the air-cooled " ATH8S " which was shown direct-coupled to an electric motor, the whole—motor, compressor and receiver—being mounted on a single steel bedframe; the set has an free air capacity of 65 cub. ft. per minute delivered against a pressure of 100 lb. per square inch. Five portable or mobile compressors were shown on the stand including a new model, the "AT8D," in which the smallest of the company's compressors is driven through V-belts by a Diesel engine; the capacity is 68 cub. ft. per minute.

Among the selection of pneumatic tools were scalers, chippers, riveters and road rippers. New models, built around a small-size cartridge-type air motor, were the 3090 Rotodrill and 30S Rotogrind, both of which are shown in Fig. 21. The grinder carries a 4-in. diameter wheel and, when fitted to an 80-lb. per square inch air supply, runs at a speed of 8,000 r.p.m.; the new drill has a limiting capacity of ½-in. steel plate. A number of rock drills were also exhibited including the largest of the range, the " SL280," a 3½-in. bore drifter, which was shown mounted on a hydraulic " Drilrig." Among the tungsten-carbide tipped drilling ancillaries were both cross-type or chisel-type drills, with either detachable tips or with bits formed on the steel and the tips brazed on.

* * *

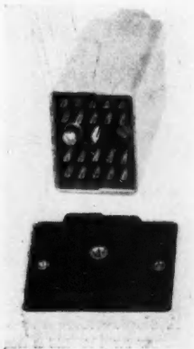
MULTI-WAY ELECTRICAL CONNECTORS

Range of Compact Units

To meet the need for interconnectors that has arisen as a result of the present tendency to build equipments from standard units, the Plessey Company, Limited, Ilford, Essex, have introduced a range of multi-way connecting plugs and sockets. These are light in weight and compact in size and are available in 20-, 30-, 40-, 60- and 80-way sizes. The socket for the 20-way size which is illustrated below measures approximately 1¾ in. by 1½ in. while the plug is 2½ in. high to the bottom of the clamp. The 80-way socket is 4¾ in. long.

The incoming cable is clamped to the plug so that there is no strain on the soldered connections. Also, the aluminium cover can be removed without disturbing the connections. In order to make soldering in the confined space easier, the rear ends of the contacts have been staggered and the hollow plug pins have been machined to allow the ingress of solder. The contacts on both plugs and sockets are silver plated and are designed to provide a positive connection when fully engaged. The contact resistance is claimed to be 1 milliohm with a carrying capacity of 2 amperes.

Plugs and sockets can be selected in any combination to give the required arrangement. For example, an 80-way socket can be used to take four 20-way, two 40-way or one 80-way plug as desired. The normal working rating is 250 volts direct current or 180 volts alternating current at any temperature between − 40 and + 70 deg. C. Insulation resistance is 100 megohms at 500 volts direct current.



The 20-way size in the range of lightweight connectors. The socket measures 1½ in. by 1¾ in.

9,000-S.H.P. MARINE DIESEL ENGINE

LOW SPEED TO GIVE DIRECT DRIVE TO PROPELLER

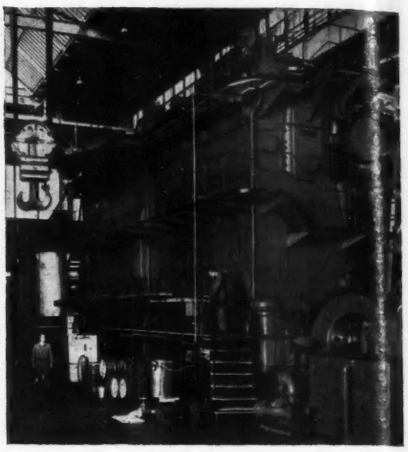
At the end of last month we visited the Winterthur works of Sulzer Brothers to see the first test-bed trials of a new 10-cylinder marine Diesel engine of a type designed specifically for cargo vessels. The particular engine, a direct reversible two-stroke unit of crosshead pattern, is to be installed in the Wonosobo, a single-screw cargo vessel of 10,500 gross tons of the Royal Rotterdam Lloyd line. The engine is shown on the test-bed and in cross-section in two of the accompanying illustrations.

In spite of the alternative claims of other forms of prime movers, the inherent fuel economy of the internal-combustion engine, enhanced by the increasing availability of cheap heavy fuel oils, makes the Diesel engine still a very suitable choice for ships of limited size. With the highest propulsion efficiency of single propellers being attained at a little over 100 r.p.m., the Diesel engine has the advantage of direct drive (thereby eliminating gear-reduction units) so long as sufficient power can be developed by a single engine and be concentrated on a single propeller shaft. The demand, however, for the design of ships both larger and faster than hitherto, requiring higher and higher outputs from the machinery, is forcing the Diesel-engine manufacturer to seek new forms which will allow even greater power outputs to be transmitted to the ship's propeller shaft.

Increasing the output of any engine may be accomplished in various ways. The mean effective pressure can be increased, but this introduces the accompanying problems of higher temperature stresses, though these may be kept relatively small by resorting to supercharging. Double-acting engines, or simply longer stroke, may be adopted, but both these methods increase the overall height of the engine with resultant increases in the space occupied and the cost of the engine. Higher engine speeds are to be avoided if gear-reduction is to be eliminated, and this leaves as a practical choice the largest feasible long-stroke engine for a direct-propeller drive.

It was to meet this requirement that Sulzers began the development of a new engine series designated the " RS " type of two-stroke engine. The first of these engines, the RS58, with a bore of 580 mm. and a stroke of 760 mm., we described in some detail at the time of the first trials (ENGINEERING, page 108, vol. 174, 1952). This engine had a rated output of 520 brake horsepower per cylinder at 240 r.p.m., in units of four to twelve cylinders; it was built for simple-geared multi-engined propulsion, so meeting only in part the requirements outlined above. From that engine, however, has been developed a later model, the RS76. For this new engine the bore has been increased to 760 mm. (29·9 in.), regarded by the designers as the limit set by the satisfactory handling of the heat stresses; the stroke has been lengthened to 1,550 mm. (61 in.) in order to attain a reasonable piston speed (approximately 1,000 ft. per minute) at the low rotational speed required. This has produced an engine having a nominal rating of 1,000 h.p. per cylinder at about 115 r.p.m., and an overall height of just over 30 ft. It can be built in units of four to twelve cylinders to give maximum output of between 4,000 and 12,000 h.p. on a direct drive to a single propeller. By this time next year the designers expect to incorporate moderate supercharging when they expect to obtain another 25 per cent. increase in power output.

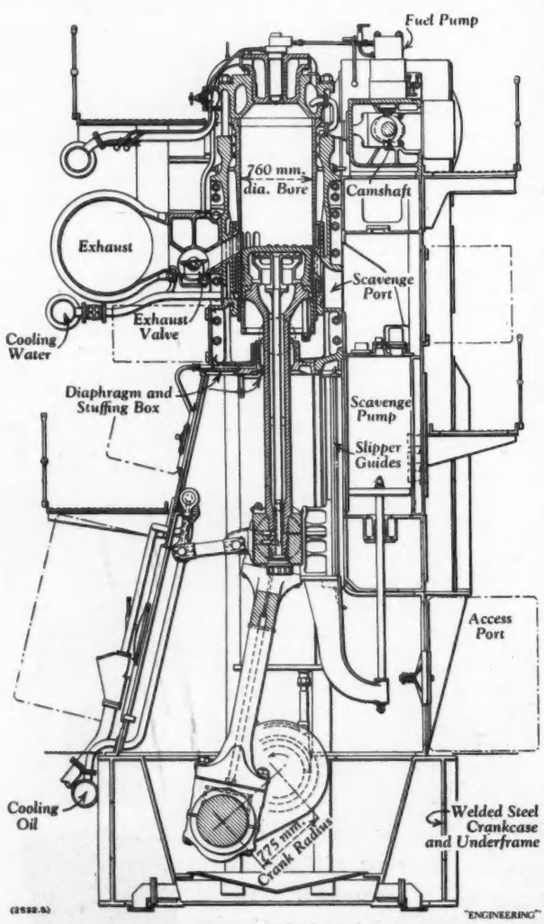
Although on the test-bed at Winterthur for the first time, some experience has already been gained with the engine because eight units, with a total of 59 cylinders, have either been completed or are now under construction, in the works of licensees. It is to meet the facilities available to those of the licensees who are unable to cast large components that the engine has been designed as a welded steel-plate structure up to the cylinder block, pre-tensioned tie bars being incorporated to give additional strength to the frames; such welded design also finds favour with some of the shipping companies.



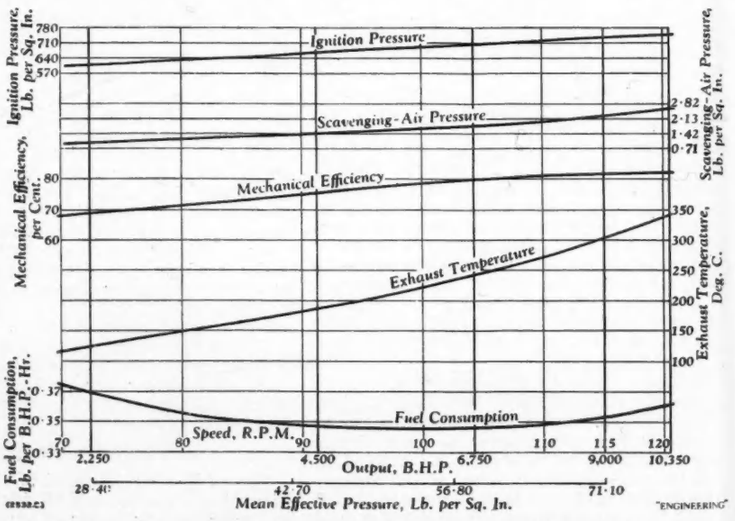
The new Sulzer marine Diesel engine, the RS76, on the test-bed. A ten-cylinder direct reversible engine, it is to be installed in the " Wonosobo," a single-screw cargo vessel of 10,500 tons.

In order to reduce the amount of dirt falling into the crankcase the cylinder is separated from the crankcase by a stuffing box around the piston rod and a diaphragm. This is of particular importance, of course, when the engine is run off some of the very heavy fuel oils which are prone to carbonising. The crankshaft is of composite construction with webs and associated crankpin being made from one piece and then shrunk on to the main journal.

A double-acting scavenge pump has been fitted beside each cylinder and is driven by a rigid arm from the crosshead slipper. The delivery chambers from the pumps are interconnected so that pressure fluctuations in the scavenging air have been kept within reasonable limits. Cross-scavenging has been employed, so avoiding a return to complicated cylinder covers weakened by valve openings and the use of involved reversing mechanisms. To minimise the head room required for dismantling, however, the piston skirt has been kept as short as possible and, as a result, the piston does not separate the scavenging air from the exhaust gases during the



A single-acting two-stroke engine of the cross-head type, the new engine has a nominal rating of 10,000 h.p. at 115 r.p.m.



Performance curves of the RS76 ten-cylinder engine as obtained from the first trials.

greater part of the stroke. Some other device—actually a special exhaust valve—has had to be provided for this purpose. It is an oscillating valve driven from an eccentric on the camshaft. The operation of the valve is so timed that the exhaust valve is closed during the upward stroke of the piston before the scavenge ports are covered by the piston although the scavenge ports are lower than the exhaust ports. This results in after-charging, the cylinder being filled with air up to the scavenging-air pressure without the need for a second and higher row of scavenge ports and their related non-return valves. Possible jamming of the exhaust valve has been avoided by allowing generous clearances on the valve plate (100 per cent. airtightness is not necessary) and serious damage due to a temporary blockage by solid particles is avoided by spring loading the connecting link from the camshaft.

To cater particularly for the use of heavy fuel oils the pipe lines have been kept very short, so eliminating high pipe-line friction losses, by locating the injection pumps just above the cylinder covers; differences in fuels are allowed for by a simple adjustment of the timing of the moment of injection. The fuel pumps, which are rated at 1,000 atmospheres, as well as the starting valves and the lubricating pumps, are driven from the camshaft, itself chain driven from the camshaft.

The fuel is heated and all the pipes are lagged to assist oil flow; composite pipes allow steam heating right up to the nozzle, which are themselves water cooled. The piston head, connecting rod, etc., are oil cooled. All the engine controls have been fitted forward. As may be seen from both the photograph and the cross-section, access to some of the chambers is facilitated by the provision of removable wall plates and hydraulic spanners are used for all dismantling, the requisite oil pressure being supplied from a small hand pump located aft.

The performance curves obtained from the initial trial run show that the engine develops 9,000 shaft horse-power at a mechanical efficiency of 83 per cent. (10,850 I.H.P.) and 115 r.p.m. These figures correspond to a mean effective pressure of 71·10 lb. per square inch (5 kg. per square centimetre) and to an ignition pressure of about 750 lb. per square inch, this latter figure being about 20 per cent. lower when the engine is developing quarter load. The exhaust temperature at full load is close to 300 deg. C. Fuel consumption is a minimum at about 70 per cent. full load. At full load, when it is about 3 per cent. more than the minimum, it is 162 gm. per brake-horse-power-hour or 0·358 lb. per brake-horse-power-hour. The power-weight ratio of the engine is quoted as 138 lb. per horse-power.

* * *

ENLARGING THE SUEZ CANAL

Passage for Bigger Ships

A scheme to widen and deepen the Suez Canal, involving the excavation of 80 million cubic yards, has been approved by an international advisory works commission which met in Paris recently. The proposals include, among other things, the cutting of two by-passes—one at Port Said, the other in the Great Bitter Lake—which will give better facilities for convoys to assemble and to pass one another; deepening of the canal throughout to allow the passage of vessels of 36 ft. draught; and widening in some sections.

At a board meeting to be held in December, the directors of the Suez Canal Company will be asked to give their authorisation for the scheme and to sanction commencement on the first instalment of the work early in 1955. The work covered by the whole scheme is expected to be spread over a period of five to six years and will be carried out in consecutive instalments in order of urgency. The improvements are designed to keep the facilities of Canal abreast of the changing requirements of modern shipping so allowing much larger ships to pass through.

THORNYCROFTS' LARGEST SHIP

MOTOR TANKER "SECHURA" LAUNCHED AT WOOLSTON

The oil tanker Sechura, which was launched on Friday, November 12, from the Woolston shipyard of John I. Thornycroft and Company, Limited, for the Peruvian Navy, has the distinction of being the largest vessel, in point of displacement, yet constructed by the firm. The occasion was marked, therefore, by an unusually large gathering, including Their Excellencies Vice-Admiral Roque A. Saldias, O.B.E., President of the Cabinet and Minister of Marine of the Republic of Peru, and Senor Dr. Don Ricardo Rivera Schreiber, K.B.E., the Peruvian Ambassador in London. The naming ceremony was to have been performed, and the vessel launched, by Her Excellency Señora Teresa de Saldias, wife of the Minister of Marine, but Her Excellency was unable to be present and, in her stead, it was carried out by Mrs. H. C. Davison, whose husband, Captain H. C. Davison, is the Peruvian Navy's inspecting officer. The launch was followed by a luncheon at which the toast of "The Ship and Her Sponsor" was proposed by Sir John E. Thornycroft, K.B.E., and acknowledged by Mrs. Davison, Vice-Admiral Saldias and Captain Davison. The response to that of "The Guests," proposed by Engineer Vice-Admiral Sir Reginald W. Skelton, K.C.B., was made by His Excellency the Peruvian Ambassador.

The Sechura has been built to the 100A1 classification of Lloyd's Register of Shipping and in conformity with the International Convention for the Safety of Life at Sea and the United States Coastguard Regulations. She has a length overall of 385 ft., a moulded breadth of 52 ft., and a moulded depth of 26 ft., and, on a displacement of 8,000 tons, will carry 6,000 tons of oil. She will be propelled by a single screw, driven by a Burmeister and Wain five-cylinder single-acting two-stroke Diesel engine, developing 2,400 brake horse-power at 120 r.p.m., which will give a sea speed of 12 knots.

There are two longitudinal corrugated bulkheads, and the transverse bulkheads are also corrugated, out to the turn of the bilge. The cargo oil tanks number 26, and there is also a hold for dry cargo, served by two 7-ton derricks on the foremast and provided with a MacGregor hatch cover. On the after side of the foremast is a 12-ton derrick for handling deck cargo.

The cargo-oil pumping system is arranged to provide the maximum of flexibility in dealing with mixed cargoes for discharge at different ports, without risk of contamination, the tank venting system being so designed that gas from one tank cannot pass into any of the others. The two horizontal duplex cargo-oil pumps are each capable of handling 300 tons an hour, and are provided with the necessary connections to enable two vessels to be fuelled alongside at once, while under way. A steam fire-extinguishing system is fitted in the cargo tanks and pump rooms, and a "total flooding" CO_2 system in the other machinery spaces, with controls amidships and aft.

Accommodation is provided in the bridge structure for the captain and chief engineer, each of whom has a day cabin and a separate sleeping cabin, and for twelve officers. The officers' dining room and lounge will seat 16 persons. The 18 petty officers have two-berth and four-berth cabins on the boat deck aft; and the 30 ratings have their sleeping quarters in the poop, and mess on the boat deck. A smokeroom is provided at the forward end of the poop. Mechanical supply and exhaust ventilation systems have been installed, capable of effecting adequate air changes for the tropical conditions in which the vessel will operate.

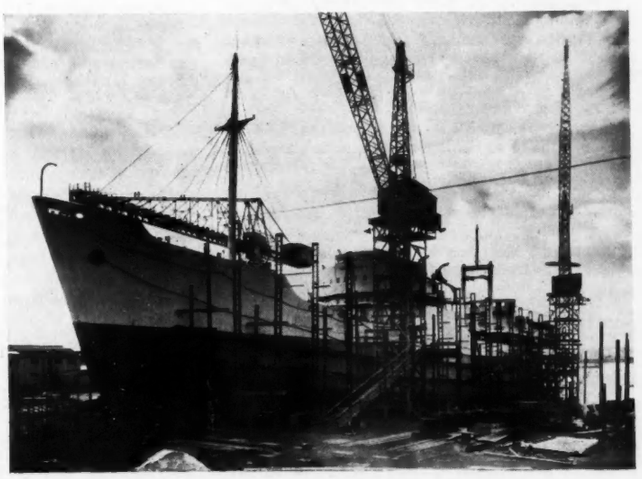
The navigation equipment includes a Sperry gyro-compass, an echo sounder, a radar installation, a Chernikeeff log, and a wireless direction-finder. The wireless transmitting and receiving installation will provide high-frequency, medium-frequency and low-frequency communication, and there is also a sound-reproduction and loud-speaker system for the diffusion of radio and gramophone programmes to the officers' and crew's quarters, and for the transmission of orders. The mooring arrangements are on an unusually liberal and substantial scale, as the vessel will operate, and refuel other ships, in waters where a heavy swell is customary. Provision has been made, therefore, for six head and six stern lines of 10 in. manila, passing through roller fairleads and secured to fabricated bollards. It is expected that the vessel will be completed in February, 1955.

* * *

NATIONAL SOCIETY OF MASTER PATTERNMAKERS

Films of technical interest will be shown at the forthcoming general meeting of the National Society of Master Patternmakers, which will be held at the Queen's Hotel, Birmingham, on Wednesday, December 1, commencing at 2.30 p.m.

The aims of the Society are to improve the status of master patternmakers and to extend the usefulness of master patternshops. Its offices are at 8 Frederick's-place, London, E.C.2.



The oil tanker "Sechura," for the Peruvian Navy, under construction at the Woolston shipyard.

FORTHCOMING EXHIBITIONS AND CONFERENCES

This list appears in the last issue of each month. An asterisk(*) indicates events appearing in the list for the first time. Particulars of forthcoming exhibitions and conferences not included below may have appeared in ENGINEERING, *October 29, page 579. Organisers are invited to send to the Editor particulars of forthcoming events as soon as arrangements are made.*

INTERNATIONAL CYCLE AND MOTOR-CYCLE EXHIBITION (32ND).—Sat., Nov. 27, to Wed., Dec. 8, in the Mechanical Engineering Pavilion, Milan Fair site, Milan. Organised by the Italian Association of Manufacturers of Cycles, Motor Cycles and Accessories, 32 Via Mauro Macchi, Milan.

POWDER METALLURGY SYMPOSIUM AND EXHIBITION.—Wed. and Thurs., Dec. 1 and 2, at Church House, Great Smith-street, London, S.W.1. Organised by the Iron and Steel Institute and the Institute of Metals. Apply to the secretary, Iron and Steel Institute, 4 Grosvenor-gardens, London, S.W.1. Tel. SLOane 0061. See ENGINEERING, April 23, page 518.

CHEMICAL AND PLASTICS EXHIBITION.—Fri., Dec. 3, to Sun., Dec. 12, at Porte de Versailles, Paris. Offices: 28 Rue Saint-Dominique, Paris, 7e. *Agents:* Butler's Advertising Service, 22 St. Giles High-street, London, W.C.2. Tel. TEMple Bar 5905.

SMITHFIELD SHOW AND AGRICULTURAL MACHINERY EXHIBITION.—Mon., Dec. 6, to Fri., Dec. 10, at Earl's Court, London, S.W.5. Inquiries to the exhibition manager, Smithfield Show, 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

*MECHANICAL ENGINEERING AS A PROFESSION.—Tues., Dec. 7, at the Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. Conference organised by the Institution. See page 684.

*INDUSTRIAL ASPECTS OF AIR POLLUTION.—Wed. and Thurs., Dec. 8 and 9, at the Cairn Hydro Hotel, Harrogate. Conference organised by the Combustion Engineering Association, 6 Duke-street, St. James's, London, S.W.1. Tel WHItehall 5536.

NATIONAL BOAT SHOW.—Thurs., Dec. 30, to Sat., Jan. 8, 1955, at Olympia, London, W.14. Inquiries to Mr. T. A. Webb, Ship and Boat Builders National Federation, 205 Regent-street, London, W.1. Tel. GROsvenor 5455.

*HIGHWAY RESEARCH BOARD, NATIONAL MEETING.—Tues., Jan. 11, to Fri., Jan. 14, 1955, at the National Academy of Sciences, Washington, D.C., U.S.A. Apply to the secretary of the Board, 2101 Constitution-avenue, Washington 25, D.C.

PACKAGING EXHIBITION, FOURTH INTERNATIONAL.—Tues., Jan. 18, to Fri., Jan. 28, 1955, at Olympia, London, W.14. Organised by Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester. Tel. Deansgate 6363.

STATIONERY TRADE FAIR.—Mon., Feb. 7, to Fri., Feb. 11, 1955, at Harrogate. Organised by the Stationers' Association of Great Britain and Ireland, 227 Strand, London, W.C.2. Tel. CENtral 7293.

BUSINESS EFFICIENCY EXHIBITION.—Tues., Feb. 8, to Fri., Feb. 11, 1955, at the Granby Halls, Leicester. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate-hill, London, E.C.4. Tel. CENtral 7771.

AGRICULTURAL MACHINERY AND EQUIPMENT EXHIBITION (INTERNATIONAL).—Sun., Feb. 13, to Sun., Feb. 20, 1955, at Brussels. Organised by the Société de Mecanique et d'Industries Agricoles S.A., 29 Rue de Spa, Brussels.

HARDWARE TRADES FAIR.—Mon., Feb. 14, to Fri., Feb. 18, 1955, at the Royal Horticultural Society's Halls, Vincent-square, London, S.W.1. Organised by Universal Exhibitions Ltd., 74 Holland Park, London, W.11. Tel. PARk 7360.

SCOTTISH NATIONAL HANDICRAFTS AND HOMECRAFTS EXHIBITION.—Thurs., Feb. 24, to Sat., Mar. 5, 1955, at the McLellan Galleries, Sauchiehall-street, Glasgow. Organisers: Henderson Exhibitions Ltd., 74 Holland Park, London, W.11. Tel. PARk 7360.

NICE INTERNATIONAL FAIR.—Sat., Feb. 26, to Mon., Mar. 14, 1955. Inquiries to the secretary, Foire de Nice, 5 Rue Hotel de Ville, Nice.

LEIPZIG INTERNATIONAL SPRING FAIR.—Sun., Feb. 27, to Wed., Mar. 9, 1955. *Agents:* Willoughby and Young, 6a Smith-street, London, S.W.3. Tel. SLOane 1594.

STATIONERY AND BOOK TRADES FAIR.—Mon., Feb. 28, to Fri., Mar. 4, 1955, at the Royal Horticultural Society's New Hall, Greycoat-street, London, S.W.1. Organised by National Newsagent Ltd., 149 Fleet-street, London, E.C.4. Tel. CITy 2604.

AGRICULTURAL MACHINERY EXHIBITION (INTERNATIONAL).—Tues., Mar. 1, to Sun., Mar. 6, 1955. *Agent:* Mr. R. C. Liebman, 178 Fleet-street, London, E.C.4. Tel. CITy 5889.

*AIR POLLUTION CONGRESS (FIRST INTERNATIONAL).—Tues. and Wed., Mar. 1 and 2, 1955, at the Hotel Statler, New York. Organised by the Society of Mechanical Engineers, 29 West 39th-street, New York, U.S.A. See page 682.

*IDEAL HOME EXHIBITION.—Tues., Mar. 1, to Sat., Mar. 26, 1955, at Olympia, London, W.14. Organised by Associated Newspapers, Ltd., New Carmelite House, London, E.C.4. Tel. CENtral 6000.

FRANKFURT INTERNATIONAL TRADE FAIR.—Sun., Mar. 6, to Thurs., Mar. 10, 1955. *Agents:* L.E.P. Transport, Ltd., Sunlight Wharf, Upper Thames-street, London, E.C.4. Tel. CENtral 5050.

VIENNA INTERNATIONAL SPRING FAIR (36TH).—Sun., Mar. 13, to Sun., Mar. 20, 1955. *Agents:* The British Austrian Chamber of Commerce, 29 Dorset-square, London, N.W.1. Tel. PADdington 7476.

ASTE WESTERN INDUSTRIAL EXPOSITION.—Mon., Mar. 14, to Fri., Mar. 18, 1955, at Los Angeles, California. Organised by the American Society of Tool Engineers, 10700 Puritan-avenue, Detroit 38, Michigan, U.S.A.

(A.S.E.E.) ELECTRICAL ENGINEERS' EXHIBITION.—Tues., Mar. 15, to Sat., Mar. 19, 1955, at Earl's Court, London, S.W.5. Sponsored by the Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. Apply to Mr. P. A. Thorogood, Electrical Engineers (A.S.E.E.) Exhibition, Ltd., 23 Bloomsbury-square, London, W.C.1. Tel. MUSeum 3450.

UTRECHT INTERNATIONAL SPRING FAIR.—Tues., Mar. 22, to Thurs., Mar. 31, 1955. *Agent:* Mr. W. Friedoff, 10 Gloucester-place, London, W.1. Tel. WELbeck 9971.

COPENHAGEN INTERNATIONAL FAIR (9TH).—Fri., Mar. 25, to Sun., April 3, 1955, Technical Section. Fri., April 15, to Sun., April 24, 1955, Commercial Section. Organised by Dansk Udstillings Syndikat A/S, Forums Anneks Julius, Thomsens Plads, Copenhagen K, Denmark.

FACTORY EQUIPMENT EXHIBITION (THIRD).—Mon., Mar. 28, to Sat., April 2, 1955, at Earl's Court, London, S.W.5. Apply to Mr. J. E. Holdsworth, 117 Kingsway, London, W.C.2. Tel. CHAncery 2318.

*PROTECTION OF STRUCTURAL STEEL.—Thurs., Mar. 31, and Fri., April 1, 1955, at the Institution of Civil Engineers, Great George-street, London, S.W.1. Symposium organised by the Corrosion Group of the Society of Chemical Industry. Communications to Mr. S. C. Britton, Tin Research Institute, Fraser-road, Perivale, Middlesex. Tel. Perivale 4254. See page 682.

SWISS INDUSTRIES FAIR.—Sat., April 16, to Tues., April 26, 1955, at Basle, Switzerland. Apply to the Swiss Legation, 18 Montague-place, Bryanston-square, London, W.1. Tel. PADdington 0701.

*LIÉGE INTERNATIONAL TRADE FAIR.—Sat., April 23, to Sun., May 8, 1955, at Liége. Organised by the Foire Internationale de Liége, 17 Boulevard d'Avroy, Liége, Belgium. *Agents:* Mattis Industries, Ltd., 252 Abbey House, Victoria-street, London, S.W.1. Tel: ABBey 7571.

PHYSICAL SOCIETY'S EXHIBITION OF SCIENTIFIC INSTRUMENTS AND APPARATUS (39TH).—Mon., April 25, to Thurs., April 28, 1955, at the Royal Horticultural Hall, Vincent-square, London, S.W.1. Organised by the Physical Society, 1 Lowther-gardens, South Kensington, London, S.W.7. Tel. KENsington 0048. See ENGINEERING, November 5, page 595.

BRITISH INDUSTRIES FAIR.—Mon., May 2, to Fri., May 13, 1955, at Olympia, London, W.14; and Castle Bromwich, Birmingham. Particulars from British Industries Fair Ltd., Ingersoll House, 9 Kingsway, London, W.C.2. Tel. COVent Garden 1461; or from the general manager, British Industries Fair, 95 New-street, Birmingham, 2. Tel. Midland 5021.

ACHEMA XI GERMAN CHEMICAL APPARATUS CONGRESS AND EXHIBITION.—Sat., May 14, to Sun., May 22, 1955, at Frankfurt-on-Main. Organised by Dechema Deutsche Gesellschaft für chemisches Apparatewesen, Rheingau-Allee 25, Frankfurt-on-Main.

NEW YORK TRADE FAIR.—Sun., May 15, to Thurs., May 19, 1955, at the Armory, 25th-street, Manhattan, New York. Organised by International Trade Shows, 545 Fifth-avenue, New York.

INTERNAL COMBUSTION ENGINE CONGRESS, INTERNATIONAL.—"COLLOQUY 1955—THE HAGUE."—Mon., May 23, to Sat., May 28, 1955, at Scheveningen, Holland. Organised by the Congrès International des Moteurs a Combustion Interne, 11 Avenue Hoche, Paris, 8e. Inquiries in Britain may be sent to the secretary of the British National Committee, c/o The British Internal Combustion Engine Manufacturers' Association, 6, Grafton-street, London, W.1. Tel. HYDe Park 5107. See ENGINEERING, September 24, page 389.

*MEDITERRANEAN FAIR (TENTH).—Wed., May 25, to Fri., June 10, 1955, at Palermo. Organised by Fiera del Mediterrano, Piazza Generale Cascino, Palermo, Italy.

*PADUA INTERNATIONAL FAIR AND PACKAGING SALON.—Sun., May 29, to Mon., June 13, 1955, at Padua. Organised by Fiera di Padova, 59 Via N. Tommaseo, Padua, Italy.

*LARGE DAMS (FIFTH CONGRESS OF THE INTERNATIONAL COMMISSION).—To open on Tues., May 31, 1955, and to be held in Paris. Apply to the British National Committee, 201–202 Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 3966. See ENGINEERING, April 2, page 448; and October 22, page 520.

BATH AND WEST AGRICULTURAL SHOW.—Wed., June 1, to Sat., June 4, 1955, at Launceston, Cornwall. Organised by the Bath and West and Southern Counties Society, 3 Pierrepont-street, Bath. Tel. Bath 3010.

BRITISH PLASTICS EXHIBITION.—Wed., June 1, to Sat., June 11, 1955, at Olympia, London, W.14. Organised by "British Plastics," Dorset House, Stamford-street, London, S.E.1. Tel. WATerloo 3333.

BUSINESS EFFICIENCY EXHIBITION.—Mon., June 6, to Thurs., June 16, 1955, at Olympia, London, W.14. Organised by the Office Appliance and Business Equipment Trades Association, 11-13 Dowgate-hill, London, E.C.4. Tel. CENtral 7771.

CONFERENCE ON COMBUSTION.—Wed., Thurs. and Fri., June 15, 16 and 17, 1955, at Cambridge, Mass., U.S.A. Organised by the American Society of Mechanical Engineers, 29 West 39th-street, New York, 18; and Tues., Wed. and Thurs., Oct. 25, 26 and 27, 1955, in London. Organised by the Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. Tel. WHItehall 7476. See ENGINEERING, September 24, page 398.

*CONFERENCE ON AUTOMATIC FACTORIES.—Thurs., June 16, to Sun., June 19, 1955, at Margate. Organised by the Institution of Production Engineers, 10 Chesterfield-street, London, W.1. Tel. GROsvenor 5254. See page 683.

SAFETY AND FACTORY EFFICIENCY EXHIBITION.—Fri., June 24, to Fri., July 1, 1955, at Bingley Hall, Birmingham. Information from the Industrial Safety Training Centre, Museum of Science and Industry, Newhall-street, Birmingham, 3.

BRITISH INSTRUMENT INDUSTRIES EXHIBITION.—Tues., June 28, to Sat., July 9, 1955, at Earl's Court, London, S.W.5. Organised by F. W. Bridges and Sons, Ltd., Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 0568.

PRINTING, MACHINERY AND ALLIED TRADES EXHIBITION (10TH).—Tues., July 5, to Sat., July 16, 1955, at Olympia, London, W.14. Promoted by the Association of British Manufacturers of Printers' Machinery (Proprietary) Ltd., Clifford's Inn, London, E.C.4. Organisers: F. W. Bridges and Sons, Ltd., Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 0568.

*SKANE (SWEDISH NATIONAL) FAIR (37TH).—Sat., July 23, to Sun., July 31, 1955, at Malmo. Organised by Skanemassan Kommissariat, Stora Nygatan 15, Malmo, Sweden.

*AUSTRIAN INTERNATIONAL EXPORT AND TRADE FAIR.—Fri., July 29, to Sun., Aug. 7, 1955, at Dornbirn, Austria. Organised by Export-U Mustermesse G.m.b.H., Dornbirn. *Agents:* British Austrian Chamber of Commerce, 29 Dorset-square, London, N.W.1. Tel PADdington 7646.

ENGINEERING, MARINE, WELDING AND FOUNDRY TRADES EXHIBITION (20TH).—Thurs., Sept. 1, to Thurs., Sept. 15, 1955, at Olympia, London, W.14. Organised by F. W. Bridges and Sons, Ltd., Grand Buildings, London, W.C.2. Tel. WHItehall 0568.

Labour Notes

"BLEAK" PROSPECTS OF BRITISH SHIPBUILDING

As a result of the heavy inroads made by modern taxation, British shipowners were finding it extremely difficult to order replacements for their older ships and the long-term outlook for the country's shipbuilding industry was rather bleak in consequence, Lord Winster told members of the Navigators' and Engineer Officers' Union in his presidential address at the opening of the union's annual general meeting in London on November 18.

There was little doubt, Lord Winster said, that the Government had been short-sighted in inflicting heavy taxation on the industry and that they had failed to realise that shipping was in every way as vital to the security of the country as the Navy, the Army and the Royal Air Force.

The shipping industry had a legitimate complaint in this respect and it stood out the more boldly when the treatment of the industry regarding taxation was compared to that meted out to the civil-aviation industry. Whereas the shipping industry was heavily taxed, civil aviation was in receipt of substantial subsidies.

At some time, possibly in the not far-distant future, the Government would have to realise that irreparable harm might be done to both the shipping and shipbuilding industries, unless something were done to lighten the burden of taxation.

OLD-AGE SHIPPING

In an outspoken address to the meeting, Mr. D. S. Tennant, C.B.E., the union's general secretary, stated that this country's share in the world's total shipping tonnage had declined by no less than 30 per cent. during the course of the last few years and that, unless remedial action was taken promptly, the share of the world's shipping that was Britain's would shrink still further.

It had to be remembered, Mr. Tennant said, that although Britain's shipping was contracting, the total world tonnage was steadily increasing. It was not sufficiently realised that nearly one-eighth of all this country's ships were over 25 years old and, therefore, in need of replacement. Some British ships, of course, were older still.

Among the motions brought before the meeting was one stating that, while the economic advantages for this country resulting from the operation of British ships in the Canadian coastal trade were fully recognised, it was considered that the wages paid to British officers in British ships should be brought into line with those paid to the officers of Canadian ships, during such periods as the British ships were employed solely in the Canadian coastal trade.

Other subjects discussed during the two-day conference, which ended on November 19, were annual leave, oil pollution, recognition for Bank Holidays spent at sea, and the necessity for an internationally-recognised document to establish the identity of seafarers.

RAILWAY ENGINEMEN'S WAGES

An award by the Railway Staff National Tribunal, announced on November 17, suggested that increases in their basic wage rates, ranging from 13*s.* to £1 6*s.* a week, be granted to railway locomotive drivers. The complementary increases in wage rates proposed by the Tribunal for firemen range from 5*s.* to 19*s.* 6*d.* a week. The award was the result of a wage claim presented to the Tribunal by the National Union of Railwaymen and Associated Society of Locomotive Engineers and Firemen on behalf of the 83,000 footplate staffs employed by British Railways.

It was ruled by the Tribunal that, if the award is accepted by the British Transport Commission and the unions, the new rates of pay for the men concerned shall be paid as from October 4 last, that being the date when the higher rates of pay for railway conciliation staffs came into force.

In almost every instance, the increases granted by the Tribunal are in excess of those offered by the Commission during negotiations with the unions on the claim. It may be noted, in this connection, that the new rate for the highest-paid drivers, although well below the demands of the Associated Society of Locomotive Engineers and Firemen, is only 2*s.* 6*d.* below the sum asked for by the National Union of Railwaymen.

The new maximum rate suggested for drivers and motormen is £9 12*s.* 6*d.* a week, compared with the old rate of £8 18*s.* 6*d.*, obtainable after six years' service in that grade. The claim of the A.S.L.E.F. had been for a maximum of £10 5*s.* a week, to be reached after three years' service, and the N.U.R. had asked for £9 15*s.* a week, to be payable after two years' service. The highest offers put forward by the Commission had been for a maximum of £8 12*s.* after three years and of £9 5*s.* after six years.

ATTITUDE OF THE UNIONS

Suggestions that the Tribunal's award would be acceptable to the Associated Society of Locomotive Engineers and Firemen were strengthened by the announcement last Friday that the union's executive council would seek an early meeting with the British Transport Commission to discuss ways and means for putting the award into operation.

This decision has been generally interpreted as implying that the award is acceptable to the union, provided that it is also acceptable to the Commission, and that a satisfactory agreement on its application can be reached. At the time of going to press, the attitude of the other union, the National Union of Railwaymen, and of the Commission, had not been made known.

The union's executive council, which was mainly responsible for the submission of the footplatemen's claim to arbitration, recognised at its meeting on the previous day that the Tribunal, having heard the whole of the facts in respect of the wage structure in the railway industry, had restored a substantial measure of the relationship between the wages of the various grades, as it formerly existed. This, a statement by the union's general secretary declared, was a feature of the railway wage situation to which the executive council had always attached great importance.

OTHER RAILWAY WAGE CLAIMS

Discussions took place on November 18 between the N.U.R. and the Commission regarding the union's desire to re-open negotiations on the agreement respecting the wage rates of the conciliation grades, which was concluded on October 8 and against which the union's rank-and-file members have expressed their "intense dissatisfaction."

Opinions expressed at the meeting were described as having been "really frank" and the discussions were eventually adjourned, to enable the union's executive committee to give further consideration to the question. It was expected that there would be a further meeting between the two sides within a few days.

Another pay claim before the Commission is that presented on behalf of the clerical and administrative staffs by the other principal railway union, the Transport Salaried Staffs' Association. Arising out of this demand, the Commission has committed itself to a further review in the near future of the rates of pay for these grades. Talks are expected to be begun in the near future.

A further demand is that put forward for a revision of the wage structure of the railway engineering employees. Claims have already been submitted by the N.U.R. and the Confederation of Shipbuilding and Engineering Unions, on behalf of these men, in terms of the conciliation-grades agreement reached last month between the Commission and the union. Some 115,000 engineering employees are affected by these demands.

CIVIL EMPLOYMENT

Persons in Great Britain employed in industry, commerce and services of various kinds numbered some 22,620,000 at the end of September. This was about the same as the total for the end of August.

An increase of nearly 50,000 in the number of men, women and juveniles employed in manufacturing industries, two-thirds of which took place in the metals, engineering and vehicle-manufacturing group, was offset by decreases in other groups. The largest of these decreases were due to seasonal declines in employment in professional, financial and miscellaneous services, and in agriculture.

In the manufacturing group of industries, the total number of persons employed at the end of September was 9,138,000, compared with a total of 9,092,000 at the end of August, an increase of 46,000. The engineering, metal-goods and precision-instrument industries, which together employed 2,680,000 persons at the end of September, was responsible for 21,000 of this increase. Employment in the vehicle-manufacturing industry rose by 7,000, to a total of 1,190,000 persons, during September.

NEW BENEFITS FOR INDUSTRIAL LUNG AND SKIN COMPLAINTS

Two schemes approved by the Minister of Pensions and National Insurance under the Industrial Diseases (Benefit) Acts, 1951 and 1954, came into operation on November 8 last.

One of these, the Pneumoconiosis and Byssinosis Benefit Amendment Scheme, extends the benefit scheme of 1952 to cover persons partially disabled by occupational diseases of the lungs, such as silicosis, absestosis and coal-miner's pneumoconiosis, or by byssinosis (chronic bronchitis caused by cotton dust), who have not previously received workmen's compensation or industrial-injuries benefit for their complaint. The scheme already covers uncompensated cases of total disablement or death from these diseases and, since its introduction, some 3,800 awards of disablement allowance and over 1,100 awards of death benefit have been made. The benefit under the amendment to the scheme, which is further explained in leaflet No. 1444 (H.M.S.O., price 4*d.* net), is 20*s.* a week and it is expected that about 15,000 persons will qualify.

The other scheme, known as the Industrial Diseases (Miscellaneous) Benefit Scheme, makes provision for similar uncompensated cases of disablement or death from certain types of skin cancer of industrial origin, or from disease due to excessive exposure to X-rays or radio-active substances. The scheme provides an allowance of 40*s.* a week (with increases in some cases) for persons who are totally disabled by an attack of one of these diseases and who have not received workmen's compensation or industrial-injuries benefit for it. Partially-disabled persons can qualify for an allowance of 20*s.* a week. The scheme also provides a death benefit of up to £300. Further information is given in leaflet No. 1443 (H.M.S.O., price 6*d.* net).

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"The Weekly Electrical Press," by R. Baldwin. North London Branch. 677 Green Lanes, Harringay, N.4. Wed., Dec. 1, 7.45 p.m.
CROYDON
"Electronics in Industry," by T. S. Worthington. South London Branch. Café Royal, North End, Croydon. Thurs., Dec. 2, 8 p.m.
PRESTON
"Universal Lighting System," by R. Pye. Preston Branch. Chamber of Commerce, 49A Fishergate, Preston. Wed., Dec. 1, 7.30 p.m.

British Institution of Radio Engineers

GLASGOW
"Interesting Applications of Electronics to Photography," by D. M. Neale. Scottish Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., Dec. 2, 7 p.m.
LIVERPOOL
"Electronics in Materials Handling," by L. Langdon Goodman. Merseyside Section. College of Technology, Byrom-street, Liverpool, 3. Thurs., Dec. 2, 7 p.m.
MANCHESTER
"Electronics and the Wind Tunnel," by G. J. Scoles. North-Western Section. College of Technology, Sackville-street, Manchester. Tues., Nov. 30, 7 p.m.

Chemical Engineering Group

BRISTOL
"Thermochemistry of Alloys," by A. R. Harding. Joint Meeting with the Institute of Metals. Chemical Department, The University, Woodlands-road, Bristol. Thurs., Dec. 2, 6.30 p.m.

Chemical Society

LONDON
Various Short Papers. Thurs., Dec. 2, 7.30 p.m.
BIRMINGHAM
"Aspects of the Organic Chemistry of Phosphorus," by Professor H. N. Rydon. Birmingham Branch. Chemistry Department, The University, Birmingham. Fri., Dec. 3, 4.30 p.m.
CAMBRIDGE
"Polymerisation of Vinyl Ethers," by Professor D. D. Eley. Cambridge Branch. Chemical Laboratory, The University, Cambridge. Fri., Dec. 3, 8.30 p.m.

Engineers' Guild

LONDON
"The Profession of the Land," by P. H. White. Metropolitan Branch. Caxton Hall, Westminster, S.W.1. Thurs., Dec. 2, 6 p.m.

Illuminating Engineering Society

CARDIFF
"Lighting for Enjoyment," by T. O. Freeth. Cardiff Centre. Offices of the South Wales Electricity Board, The Hayes, Cardiff. Thurs., Dec. 2, 5.45 p.m.
EDINBURGH
"What Do We Know About Lighting?" by R. J. Fothergill. Edinburgh Centre. 12 Rothesay-place, Edinburgh. Wed., Dec. 1, 7 p.m.
GLASGOW
"Dock and Railway Lighting," by W. T. F. Souter. Glasgow Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., Dec. 2, 7.30 p.m.
HULL
Four papers on "Industrial Lighting." Leeds Centre. Offices of the Yorkshire Electricity Board, Ferensway, Hull. Mon., Nov. 29, 7.30 p.m.
NOTTINGHAM
"A New Approach to Lighting Design," by W. Robinson. Nottingham Centre. Offices of the East Midlands Electricity Board, Smithy-row, Nottingham. Thurs., Dec. 2, 6 p.m.

Incorporated Plant Engineers

LEEDS
"Fuel-Injection Equipment for High-Speed Oil Engines," by W. H. Simpson. West and East Yorkshire Branch. The University, Leeds. Mon., Nov. 29, 7.30 p.m.
LEICESTER
Various short papers. Leicester Branch. Leicester College of Art and Technology, The Newarkes, Leicester. Wed., Dec. 1, 6.30 p.m.
PETERBOROUGH
Discussion on "Railway Electrification." Peterborough Branch. Offices of the Eastern Gas Board, Church-street, Peterborough. Thurs., Dec. 2, 7.30 p.m.
SOUTHAMPTON
"Prevention of Industrial Accidents," by T. W. Thompson. Southampton Branch. Polygon Hotel, Southampton. Wed., Dec. 1, 7.30 p.m.

Institute of British Foundrymen

CARDIFF
"Foundry Pelleted Pitch," by T. F. N. Matthews and G. Smart. Wales and Monmouth Branch. South Wales Institute of Engineers, Park-place, Cardiff. Sat., Dec. 4, 6 p.m.
MANCHESTER
"Production of Heavy Steel Castings," by S. Taylor. Lancashire Branch. Engineers' Club, Albert-square, Manchester. Sat., Dec. 4, 3 p.m.

Institute of Fuel

CARDIFF
"Sulphur Removal and Recovery from Fuels," by Dr. J. G. King. South Wales Section. South Wales Institute of Engineers, Park-place, Cardiff. Fri., Dec. 3, 6 p.m.
EDINBURGH
"The Constitution of Coal: Modern Theories," by Dr. A. Whitaker. Scottish Section. North British Hotel, Edinburgh. Fri., Dec. 3, 7 p.m.

Institute of Metals

BIRMINGHAM
Students' Evening. Birmingham Local Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Dec. 2, 6.30 p.m.

Institute of Road Transport Engineers

PETERBOROUGH
"The Development of the Gas Turbine and Its Application to Road Transport," by P. A. Phillips. Eastern Centre. Museum Art Gallery, Peterborough. Wed., Dec. 1, 7 p.m.

Institute of Welding

LONDON
"Composition of Weld Metal," by W. P. van den Blink. North London Branch. Manson House, 26 Portland-place, W.1. Thurs., Dec. 2, 7.30 p.m.

Institution of Chemical Engineers

CARDIFF
"Observations on the Design and Commissioning of Chemical Plants," by B. L. Budd. South Wales Graduates' and Students' Section. University College of South Wales and Monmouthshire, Cathays Park, Cardiff. Wed., Dec. 1, 7 p.m.
NEWCASTLE-UPON-TYNE
"Crystallisation from Organic Melts," by J. S. Forsyth. North-East Graduates' and Students' Section. Stephenson Building, Claremont-road, Newcastle-upon-Tyne. Fri., Dec. 3, 6.15 p.m.

Institution of Civil Engineers

ONDON
"Prestressed Units for Short-Span Highway Bridges," by A. D. Holland. Tues., Nov. 30, 5.30 p.m.
MANCHESTER
"Peace-Time Activity of the Corps of Royal Engineers," by Brigadier A. N. Anstruther. Engineers' Club, Albert-square, Manchester. Thurs., Dec. 2, 6.30 p.m.
NOTTINGHAM
"Concrete Shuttering," by H. Parry. Midlands Association. Offices of the East Midlands Gas Board, Lower Parliament-street, Nottingham. Tues., Nov. 30, 6.30 p.m.

Institution of Electrical Engineers

LONDON
Discussion on "The Servicing of Electronic Measuring Instruments and Its Effect on Their Design," opened by Dr. Denis Taylor. Measurements Section. Tues., Nov. 30, 5.30 p.m.
"Vertical Radiation Patterns of Medium-Wave Broadcasting Aerials," by H. Page and G. D. Monteath. Radio Section. Wed., Dec. 1, 5.30 p.m.
"The Electrification of the Manchester-Sheffield-Wath Lines, Eastern and London Midland Regions, British Railways," by J. A. Broughall and K. J. Cook. Thurs., Dec. 2, 5.30 p.m.
ARBORFIELD, BERKSHIRE
Film Evening. London Students' Section. R.E.M.E. Training Centre, Hazebrouck Barracks, Arborfield, Berkshire. Tues., Nov. 30, 7 p.m.
BIRMINGHAM
"Nuclear Reactors and Power Production," by Sir Christopher Hinton. South Midland Centre. Joint Meeting with the Institutions of Civil and Mechanical Engineers. Midland Institute, Birmingham. Wed., Dec. 1, 6.30 p.m.
CAMBRIDGE
"Electricity Supply Problems in Cambridge," by A. C. Eden. East Midland Centre. Cavendish Laboratory, Cambridge. Tues., Nov. 30, 6.30 p.m.
HULL
"Aluminium-Sheathed Cables," by P. M. Hollingsworth and P. A. Raine. North Midland Centre. Offices of the Yorkshire Electricity Board, Ferensway, Hull. Thurs., Dec. 2, 7.15 p.m.
LIVERPOOL
"A Short Modern Review of Fundamental Electromagnetic Theory," by P. Hammond. Mersey and North Wales Centre. Liverpool Royal Institution, Colquitt-street, Liverpool. Mon., Nov. 29, 6.30 p.m.

Institution of Engineering Inspection

BIRMINGHAM
"Dynamic Balancing," by A. Binns. Birmingham Branch. Birmingham Chamber of Commerce, 95 New-street, Birmingham. Wed., Dec. 1, 7.30 p.m.
COVENTRY
"Recent Developments in Metrology, with Special Reference to Interferometry," by W. Foster. Coventry Branch. Technical College, Coventry. Tues., Nov. 30, 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Components of the Propulsive Efficiency of Screw Vessels," by G. Johnson. Tues., Nov. 30, 7.30 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"Problems and Methods of Smoke Prevention," by T. F. Hurley and L. J. Flaws. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Dec. 1, 6 p.m.
NOTTINGHAM
John Johnson Night of Problems and Experiences. Nottingham Branch. College of Arts and Crafts, Saverley-street, Nottingham. Wed., Dec. 1, 6.30 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "Planning and Operation of Maintenance Schedules for Steam Power Plants." Steam Group. Tues., Nov. 30, 6.45 p.m.
Discussion "The Relative Merits of Full-Flow and Bypass Filtration in High-Speed-Engine Lubrication Systems." Internal Combustion Engine Group. Thurs., Dec. 2, 6.45 p.m.
"The Roll-Setting Method of Automatic Control of Gauge in Hot and Cold Rolling Mills," by R. B. Sims and K. H. Slack Fri., Dec. 3, 5.30 p.m.
ABERDEEN
"Shrink Fit Investigations on Simple Rings and on Full-Scale Crankshaft Webs," by Professors A. S. T. Thomson and A. W. Scott and Dr. C. M. Moir. Sir Robert Gordon's Technical College, Aberdeen. Fri., Dec. 3, 7.30 p.m.
BIRMINGHAM
James Clayton Lecture on "Nuclear Reactors and Power Production," by Sir Christopher Hinton. Midland Branch. Joint Meeting with the Institutions of Civil and Electrical Engineers. Midland Institute, Birmingham. Wed., Dec. 1, 6.30 p.m.
BRISTOL
"The Accountancy Service to Works Management," by C. E. Power. Western Branch. Grand Hotel, Bristol. Wed., Dec. 1, 7 p.m.
CHICHESTER
"Engineering Aspects of a Public Water Supply," by T. Irvine Hudson. Southern Branch. Dolphin Hotel, Chichester. Wed., Dec. 1, 6 p.m.
GLASGOW
"Shrink Fit Investigations on Simple Rings and on Full-Scale Crankshaft Webs," by Professors A. S. T. Thomson and A. W. Scott and Dr. C. M. Moir. Royal Technical College, George-street, Glasgow. Thurs., Dec. 2, 7.30 p.m.

Institution of Production Engineers

BEDFORD
"Noise and Vibration in Machinery," by Dr. A. J. King. Luton Section. Works of W. H. Allen, Sons & Co., Ltd., Bedford. Tues., Nov. 30, 7.15 p.m.
HUDDERSFIELD
Brains Trust on "Production." Halifax Section. George Hotel, Huddersfield. Wed., Dec. 1, 7.15 p.m.
NORWICH
"Planned Maintenance," by O. F. Lewis. Norwich Section. Assembly House, Theatre-street, Norwich. Fri., Dec. 3, 7.30 p.m.
SWANSEA
"Planning for Production," by B. E. Stokes. West Wales Section. Central Library, Alexandra-road, Swansea. Fri., Dec. 3, 7.30 p.m.
WOLVERHAMPTON
"Control of Production as Applied to the Manufacture of Small Internal-Combustion Engines," by D. Dudfield. Wolverhampton Section. Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. Wed., Dec. 1, 7.15 p.m.

Institution of Sanitary Engineers

LONDON
"Biological Sewage Filtration and Vacuum Dewatering of Sludge: Experimental Work at Reading," by D. H. Barraclough. Caxton Hall, Westminster, S.W.1. Thurs., Dec. 2, 6 p.m.

Institution of Structural Engineers

BRISTOL
"Highlights in an Engineer's Life," by J. Guthrie. Western Counties Branch. The University, Bristol. Fri., Dec. 3, 6 p.m.
MANCHESTER
"Design Features and Collapse of the Tacoma Narrows Bridge," by S. M. Cooper. Lancashire and Cheshire Branch. College of Technology, Manchester. Mon., Nov. 29, 6.30 p.m.

Junior Institution of Engineers

LONDON
Film Evening. Fri., Dec. 3, 7 p.m.
BIRMINGHAM
Chairman's Address on "Tropical Aquaria Electrical Apparatus," by C. H. Crawford. Midland Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Wed., Dec. 1, 7 p.m.

Royal Institution

LONDON
"Industrial Power from Nuclear Energy," by Sir Christopher Hinton. Fri., Dec. 3, 9 p.m.

Royal Society

LONDON
Anniversary Meeting. Tues., Nov. 30, 2.30 p.m.

Royal Society of Arts

LONDON
"Insulation of Modern Submarine Cable," by J. V. Dean. Wed., Dec. 1, 2.30 p.m.
"Broadcasting in the Colonies," by J. Grenfell Williams. Commonwealth Section. Thurs., Dec. 2, 5.15 p.m.

Royal United Service Institution

LONDON
"The Integration of National Service with the Country's Economic Future," by Major-General C. Lloyd. Wed., Dec. 1, 3 p.m.

Sheffield Metallurgical Association

SHEFFIELD
Discussion on "Acid Roofs of Open-Hearth Furnaces." B.I.S.R.A. Laboratories, Hoyle-street, Sheffield, 3. Tues., Nov. 30, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Engineering Group, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Engineers' Guild, 78 Buckingham-gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Inspection, 28 Victoria-street, London, S.W.1. (ABBey 3794.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Sanitary Engineers, 118 Victoria-street, London, S.W.1. (VICtoria 3017.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Royal United Service Institution, Whitehall, London, S.W.1. (WHItehall 5854.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)